DØ Status and Prospects

DOE Program Review, Fermilab, March 19, 2002

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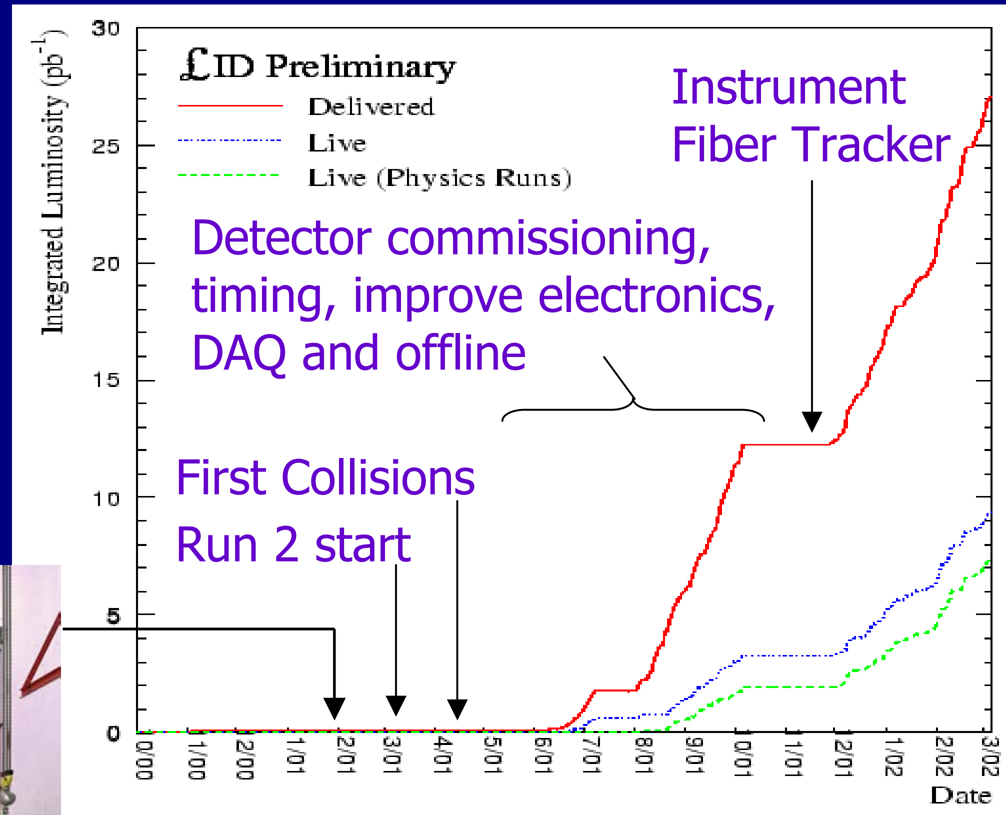
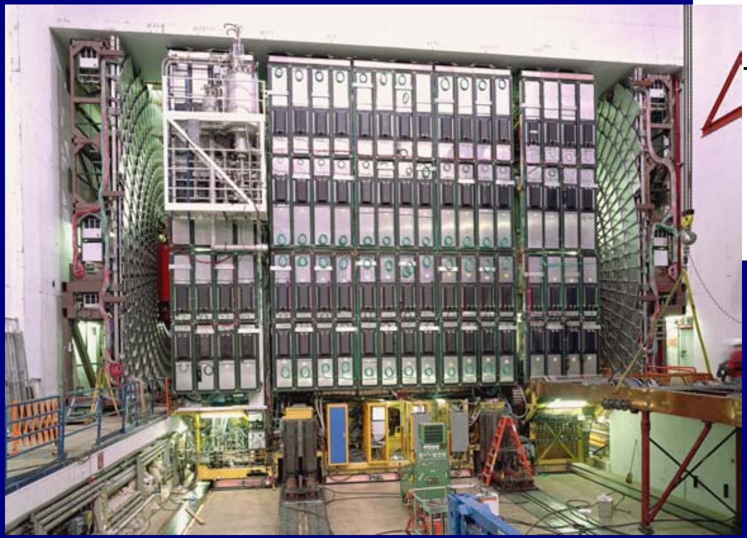
DØ

- DØ is an international collaboration of ~ 600 physicists from 18 nations who have designed, built and operate a collider detector at the Tevatron
- Physics goals
  - Precise study of the known quanta of the Standard Model
    - Weak bosons, top quark, QCD, B-physics
  - Search for particles, forces beyond those known
    - Higgs, supersymmetry, extra dimensions, other new phenomena
- Driven by these goals, the detector emphasises
  - Electron, muon and tau identification
  - Jets and missing transverse energy
  - Flavor tagging through displaced vertices and leptons

The past year

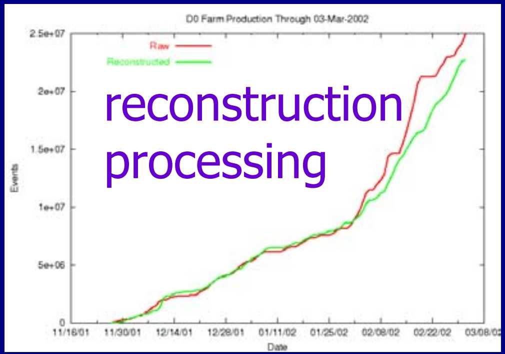
- About 25 pb^{-1} delivered so far
- Used for commissioning of
  - Detectors
  - Offline processing
  - Worldwide data access
  - Analysis
    - e, μ, jets, EM and jet energy scales, etc.



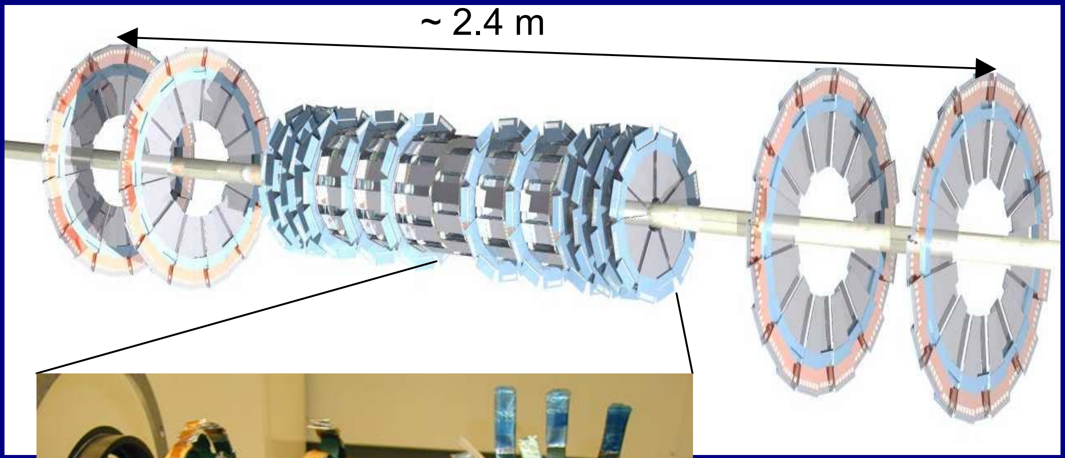


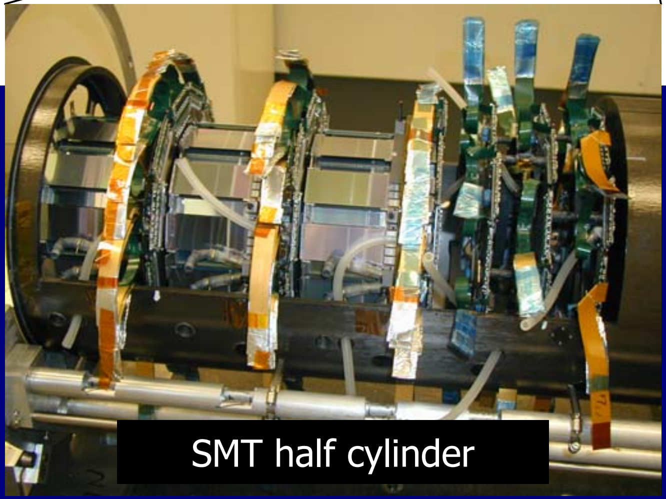
DØ detector roll-in

~ 12 pb^{-1} now on tape



Silicon Microstrip Tracker

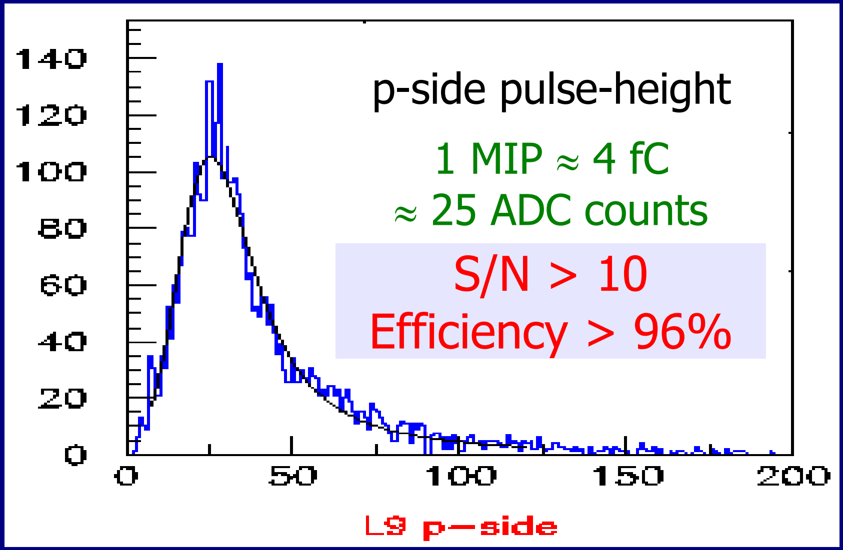




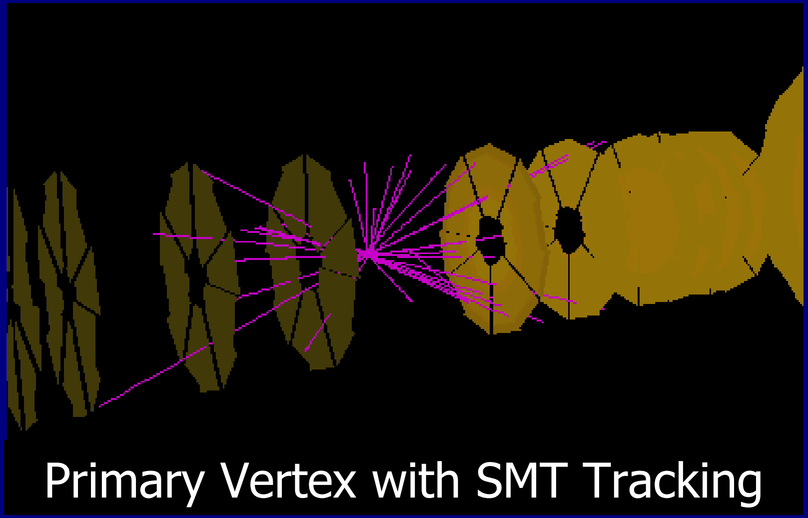
- ~ 800,000 channels
- 6 barrels with interspersed disks
- 4 external disks for forward tracking ($2 < |\eta| < 3$)
- 4 layers of single sided (axial) and double sided (axial+stereo) detectors
- 3D track reconstruction capabilities

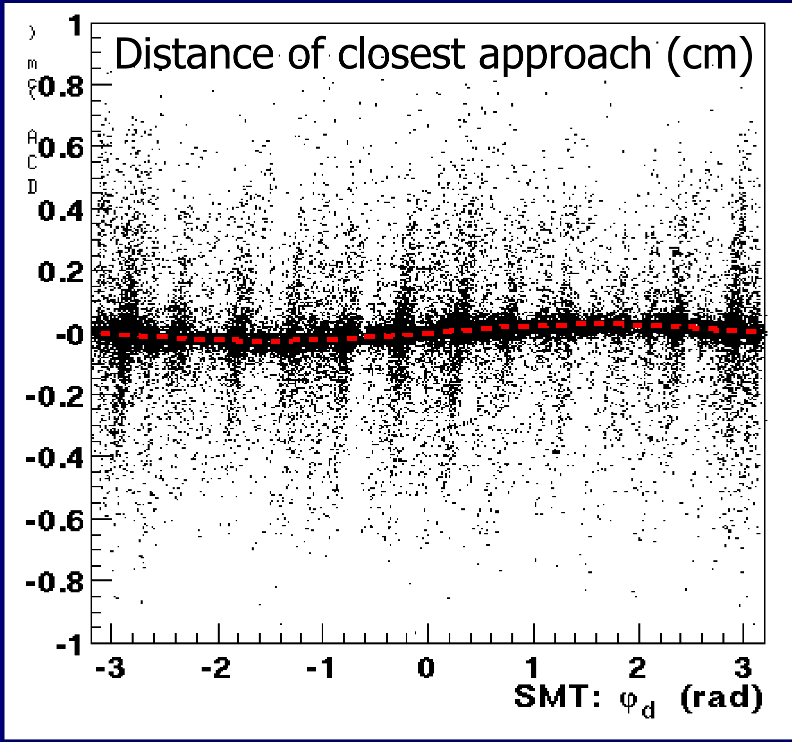
<u>100% commissioned</u>

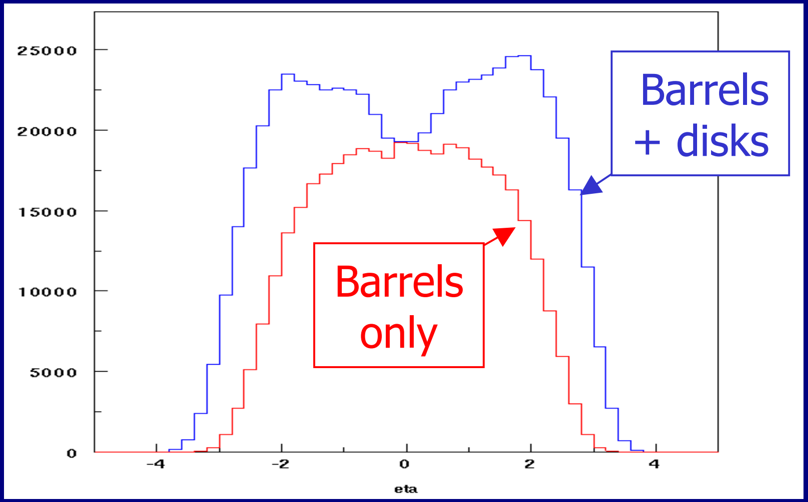
Barrels: 95.2% operational
F-disks: 95.8% operational
H-disks: 86.5% operational



Silicon tracking







Whole DØ Detector moved ~ 5mm (November 2001) to center it on the beamline

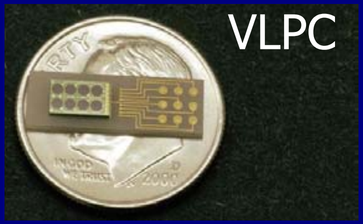
Successful within a few hundred microns

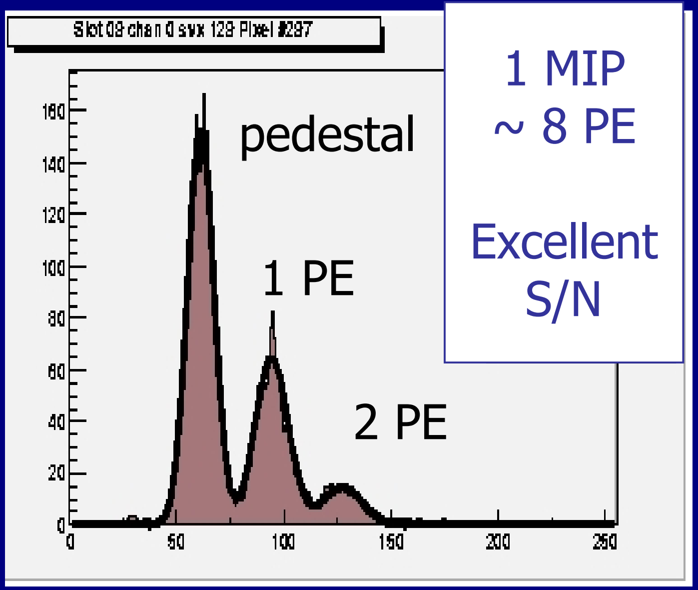
Meets requirements of Level 1 and Level 2 track triggers

Work in progress:
Integrating disks into tracking

Central Fiber Tracker

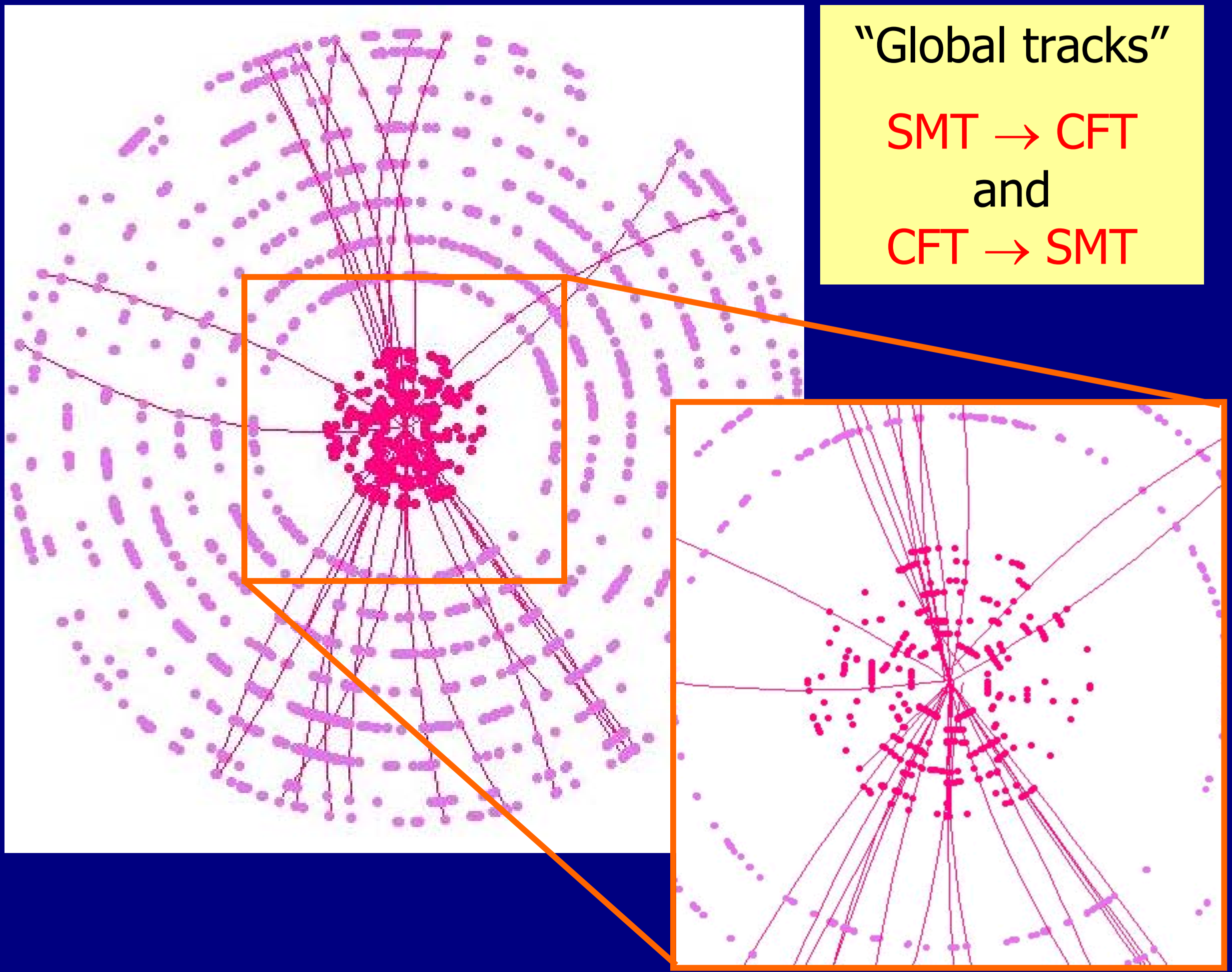
- 8 layers of axial and stereo fibers (20 < r < 51 cm), 77k channels
- ~12m long clear light-guides to Visible Light Photon Counters (VLPC) under detector
  - 9K operating temperature
  - 85% QE, excellent S/N
  - Fast pick-off for trigger





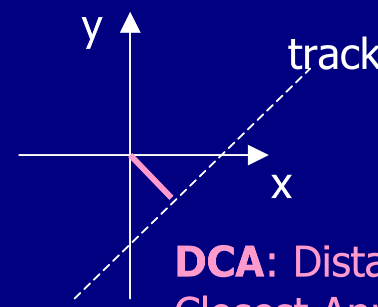
Axial: 100% readout; Stereo: 52% readout
Fully commissioned by mid-April

Track reconstruction

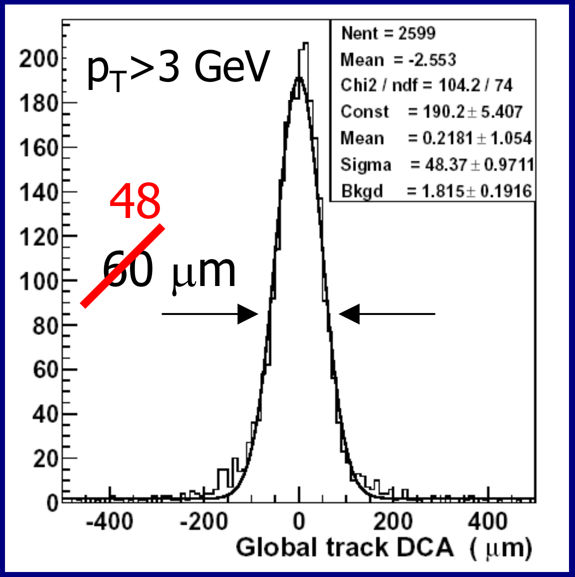


"Global tracks"

SMT → CFT
and
CFT → SMT



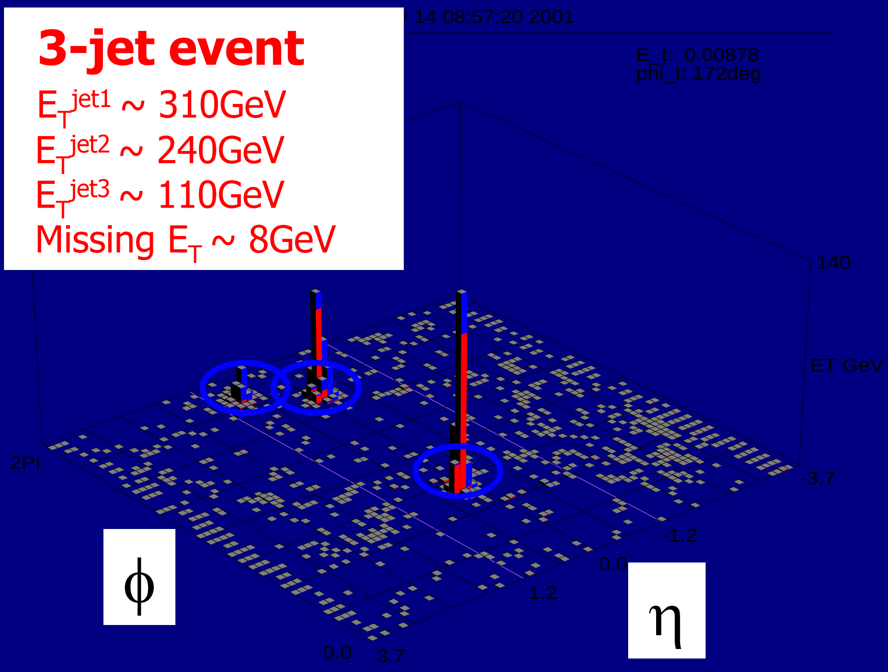
DCA: Distance of Closest Approach

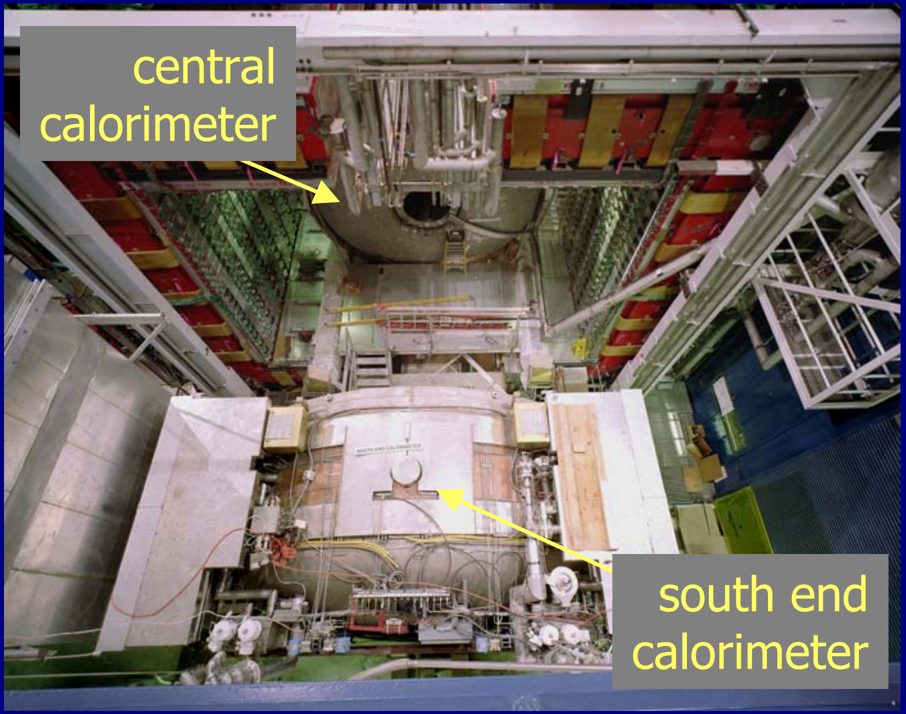


DCA resolution ~ 50 μm (using as built + surveyed alignment)
beam spot ~ 30-40 μm

Calorimeter

- Uranium-Liquid Argon
  - stable, uniform response, radiation hard, fine segmentation
- Uniform, hermetic, full coverage
  - $|\eta| < 4.2$
- Compensating ($e/\pi \sim 1$)
- Good energy resolution





Excellent performance demonstrated in Run 1

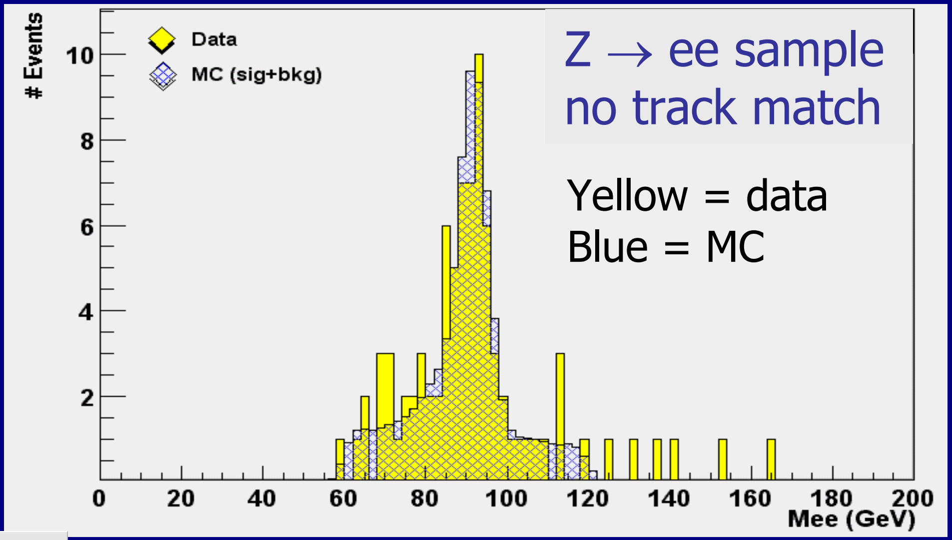
<u>100% commissioned</u>

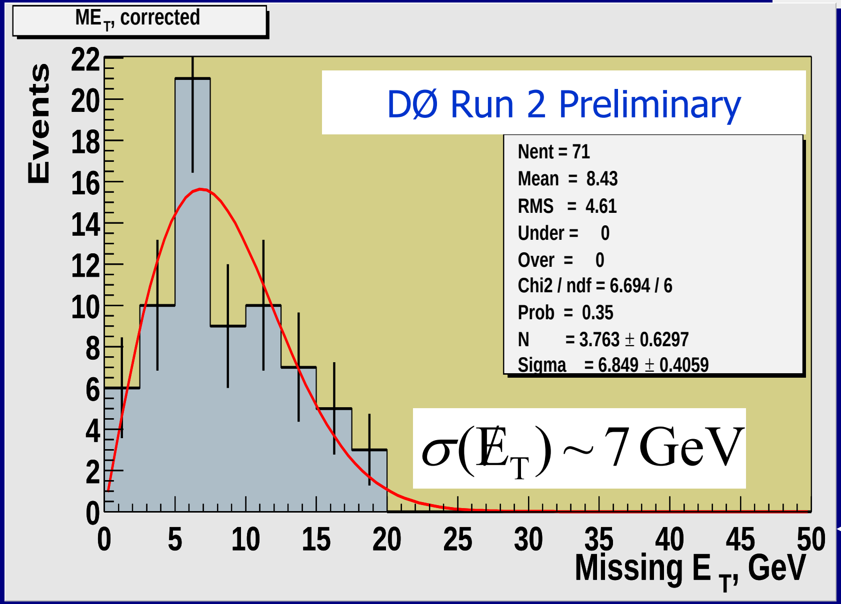
~55K readout channels

~0.1% dead/noisy

Calorimeter performance

- As in Run 1, the EM energy scale is set by $Z \rightarrow e^+e^-$
  - EM resolution modeled well by Monte Carlo

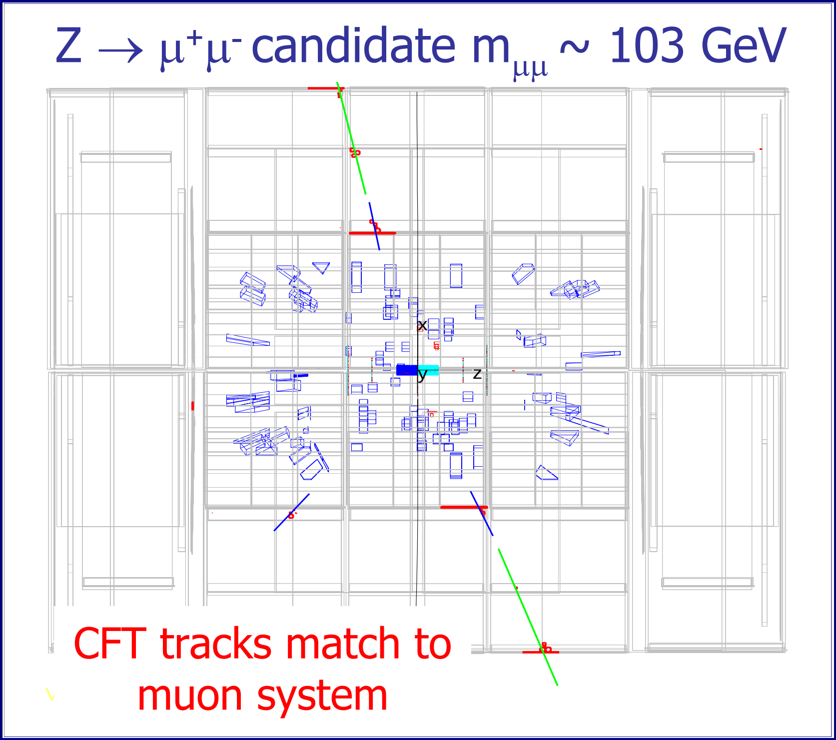


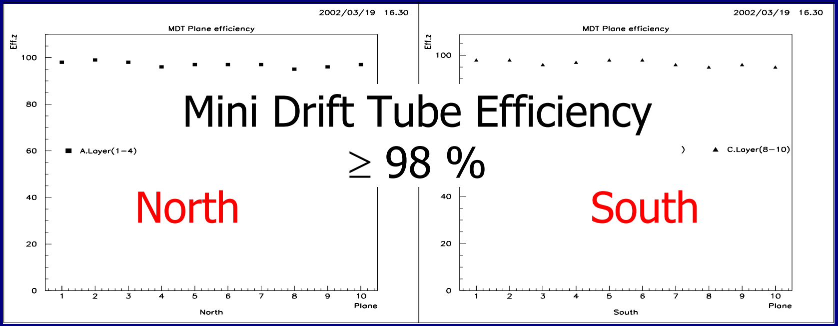


- Missing E_T important for new physics searches
  - SUSY, extra dimensions, etc.
- Determine ME_T resolution from inclusive di-electron sample with at least one track match (Z, DY)

Snapshot of present performance

Muon System





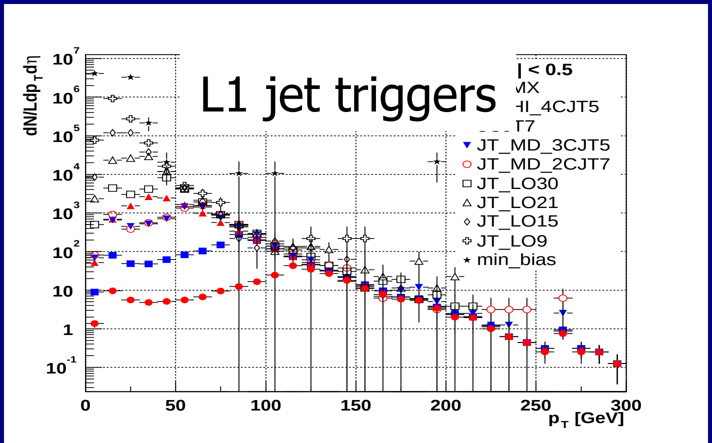
- Coverage to $|\eta|<2$
- Scintillator trigger planes plus drift tubes for track reconstruction
- Rough standalone momentum measurement, to be used with inner tracking
- Thorough shielding and good time resolution (~2.5 ns) reduces out-of-time backgrounds and cosmics

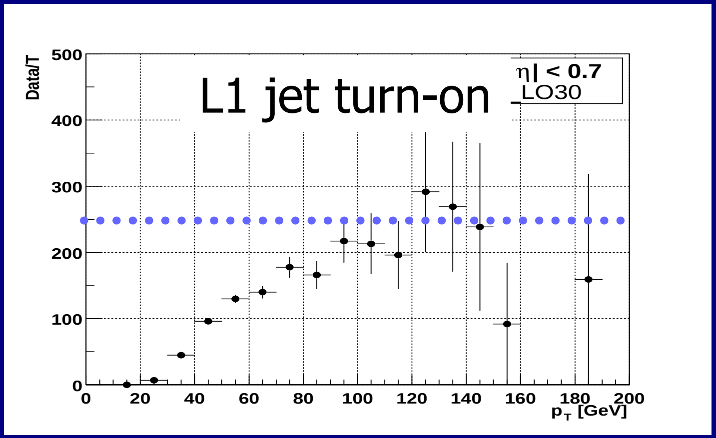
Muon system 100% commissioned

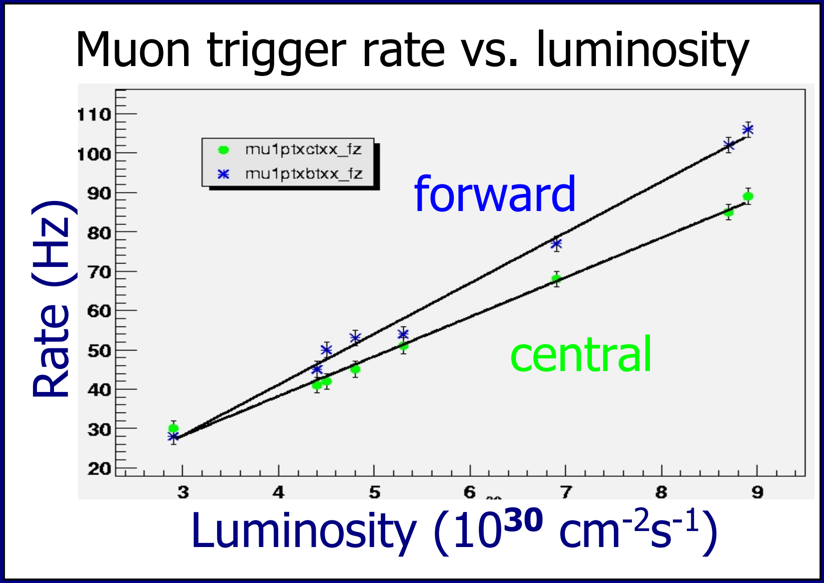
Trigger systems

One area where there is still work to be done

- Level 1
  - Calorimeter and muon system triggers working very well





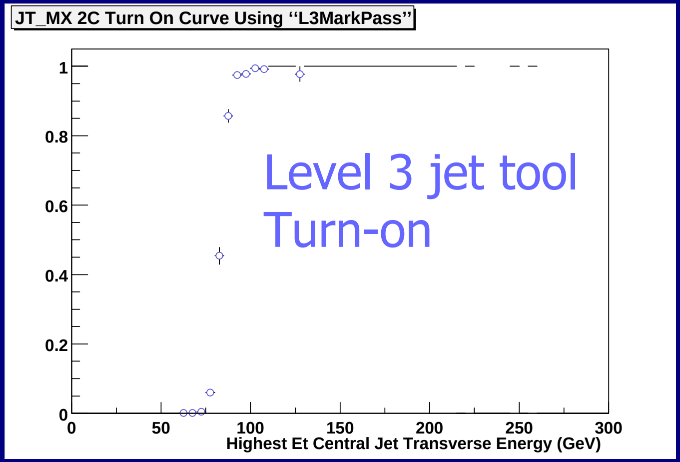


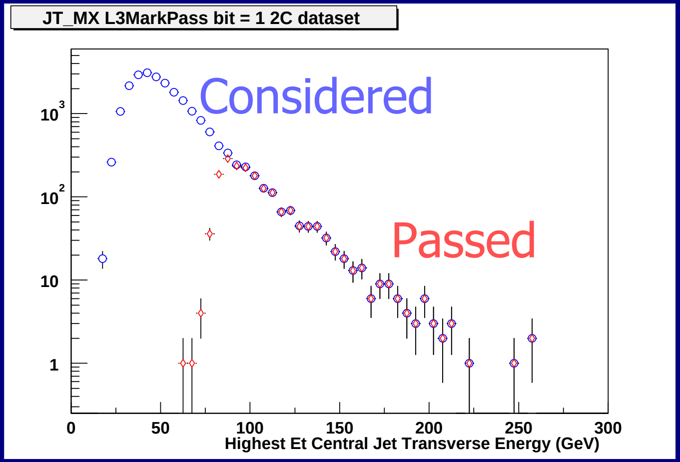
Level 1 central track trigger coming

Evolution of our trigger matches laboratory's luminosity plan

- Level 2
  - Technically ready to reject but still a few weeks' work on algorithms
  - Silicon track trigger coming this summer
- DAQ
  - Technical problems with baseline implementation led to decision to move to an ethernet based system
    - uses single-board computers in VME crates and Cisco switches
  - Strong team, good progress
    - excellent role played by Fermilab Computing Division
  - Adiabatic upgrade path with full system in place this summer
- Level 3
  - 48-node Linux level 3 farm installed, working and selecting events:

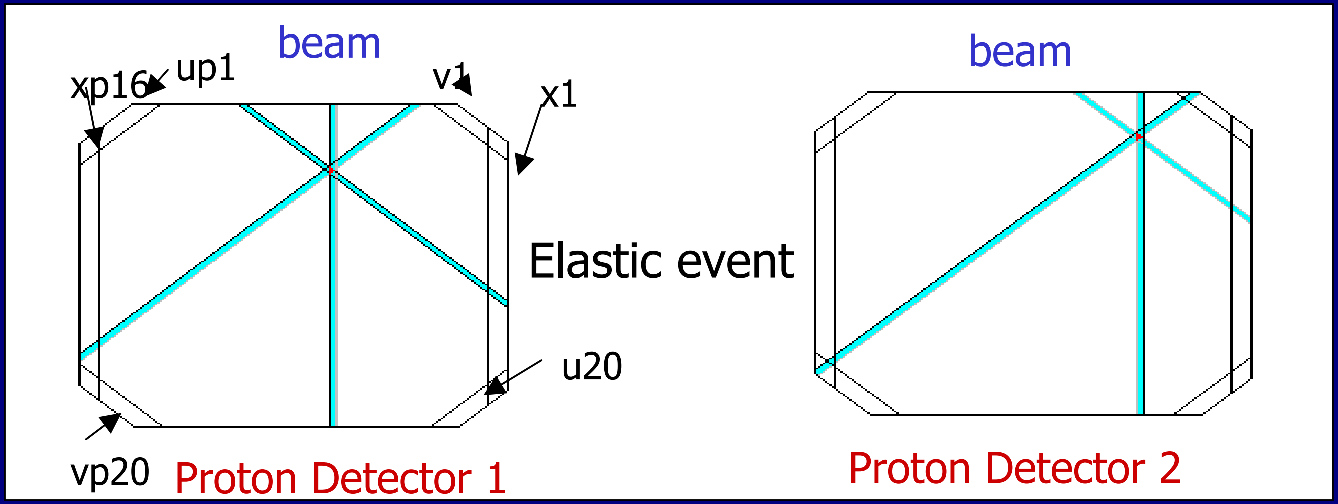
switched to new software at end of March



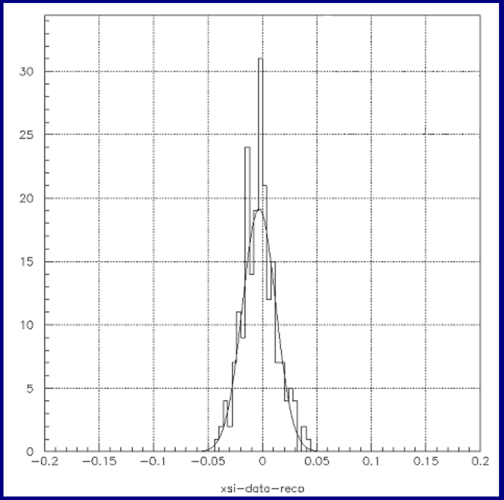


Forward Proton Detector

Scintillating fiber detectors in Roman pots near beam used to tag protons and anti-protons



$\xi (= \Delta p/p)$ distribution for a sample of clean elastic events:

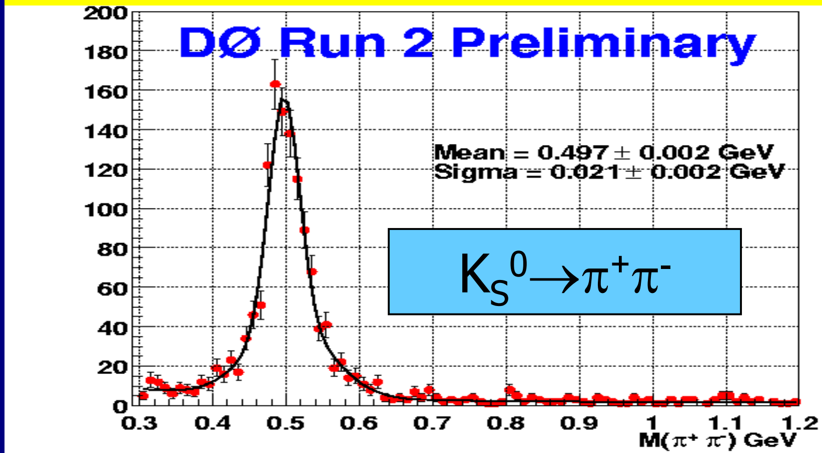


Commissioning in progress, integration with central detector in summer

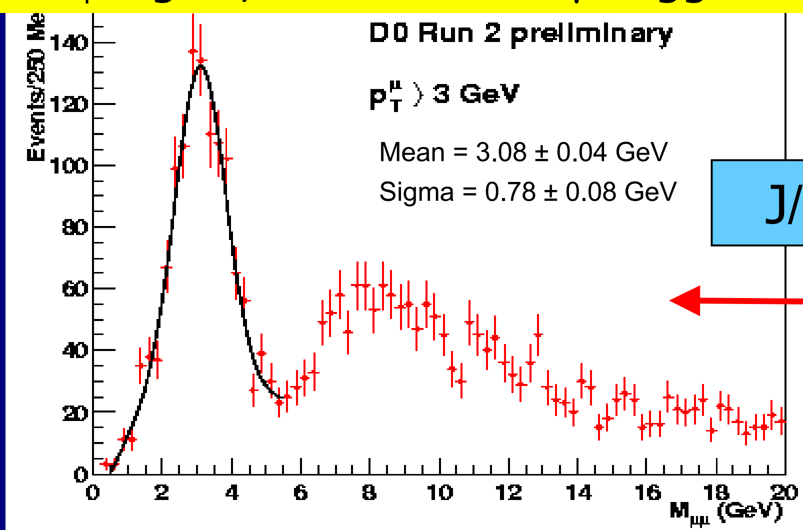

Fermilab
Michigan St.
Michigan
Indiana
Boston
Kansas
Oklahoma
Arizona
Texas
La. Tech
SAM data transfer
Monte Carlo files
Lancaster
Imperial
NIKHEF
Prague
Lyon
Wuppertal
Munich
DØ
DØ worldwide data grid status March 2002
5 remote Monte Carlo generation sites + more coming
16 SAM stations for remote analysis + more coming

On the road to b-physics

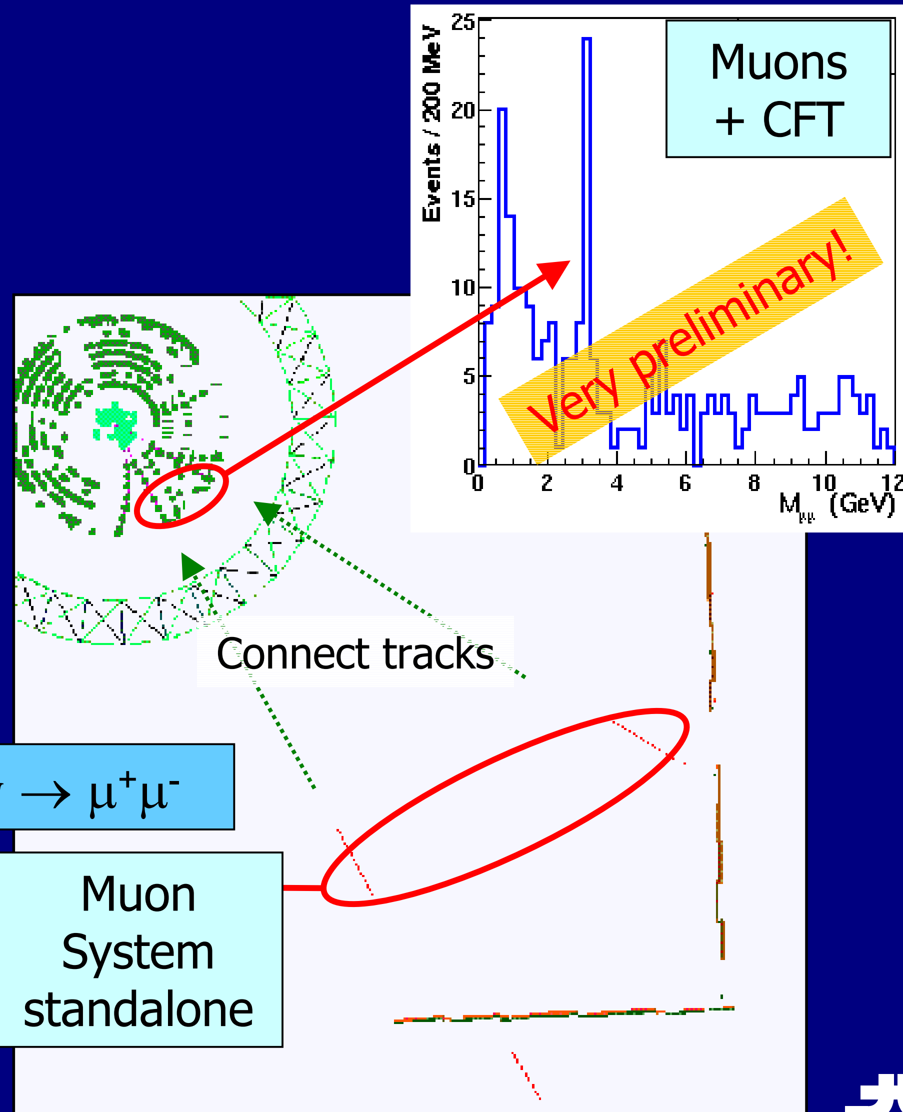
K⁰ signal, silicon standalone tracking



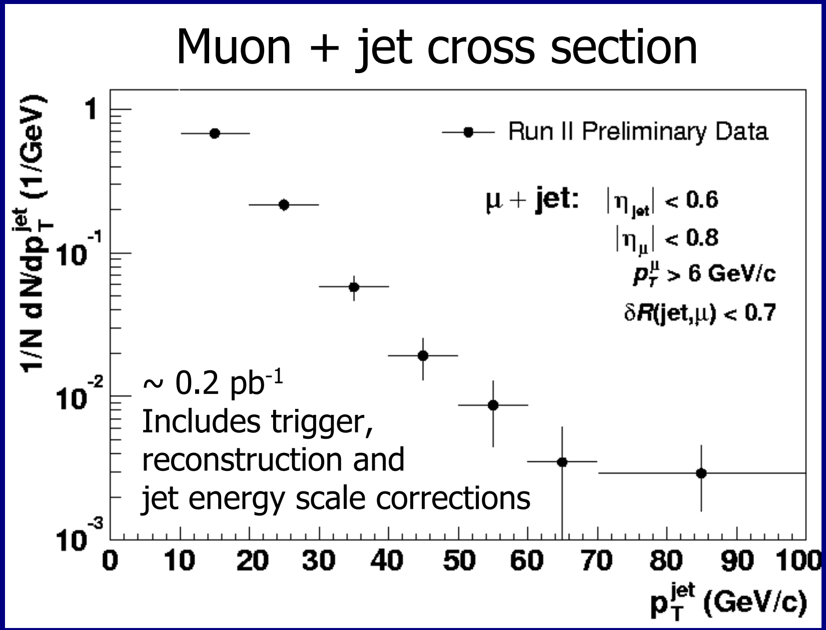
J/ψ signal, central + fwd μ triggers

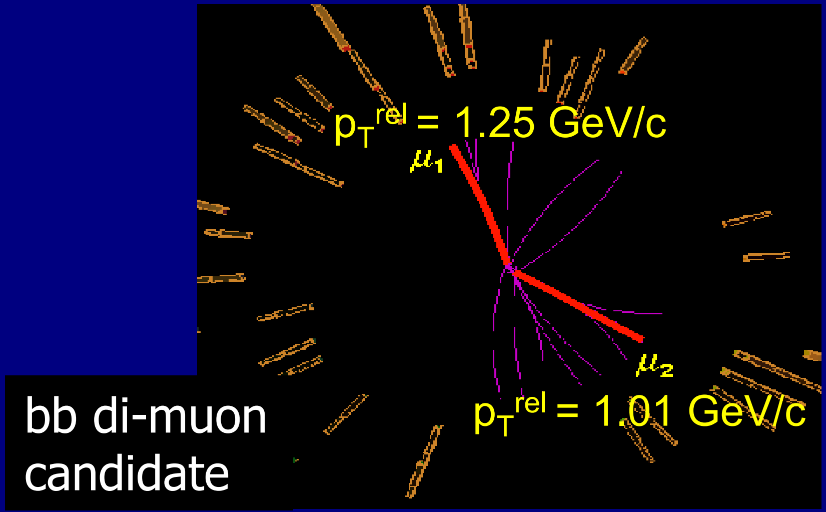


$J/\psi \to \mu^+\mu^-$

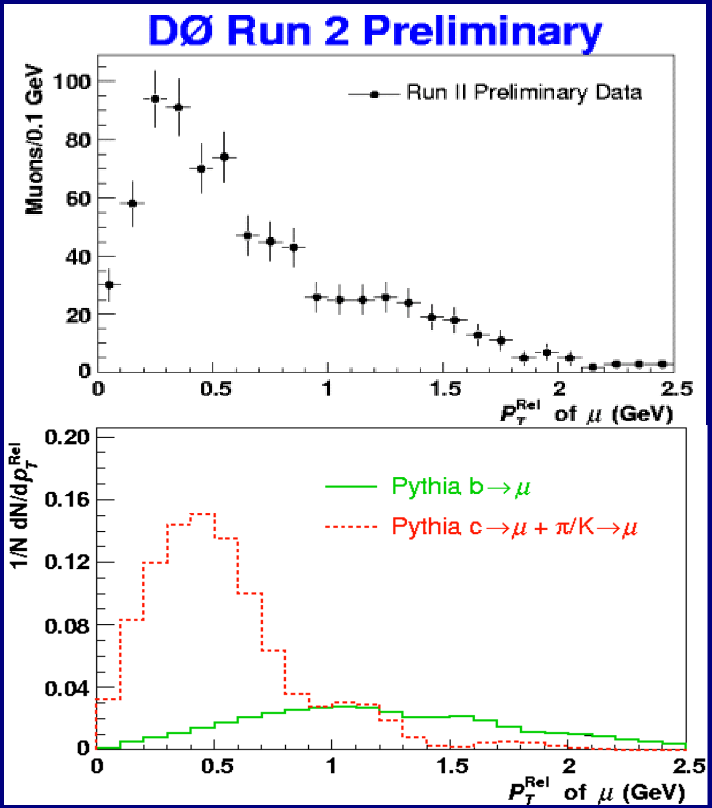


On the road to b cross sections





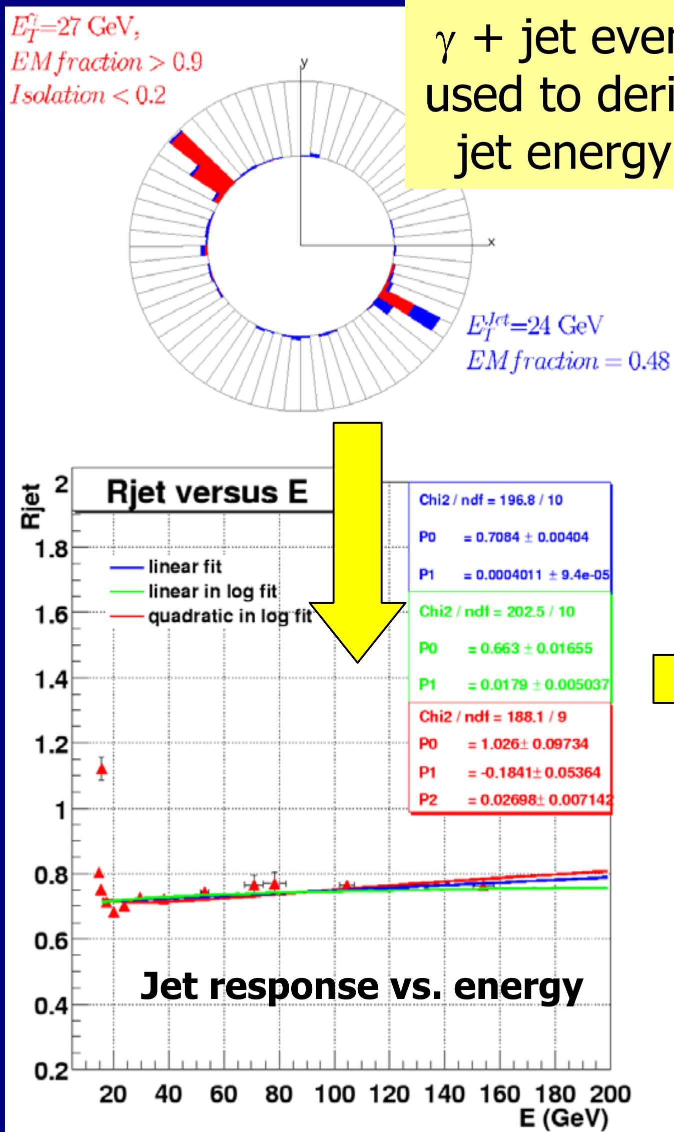
- Cross section consistent in shape with DØ Run I results in same kinematic region
- p_T of the muon relative to the jet:

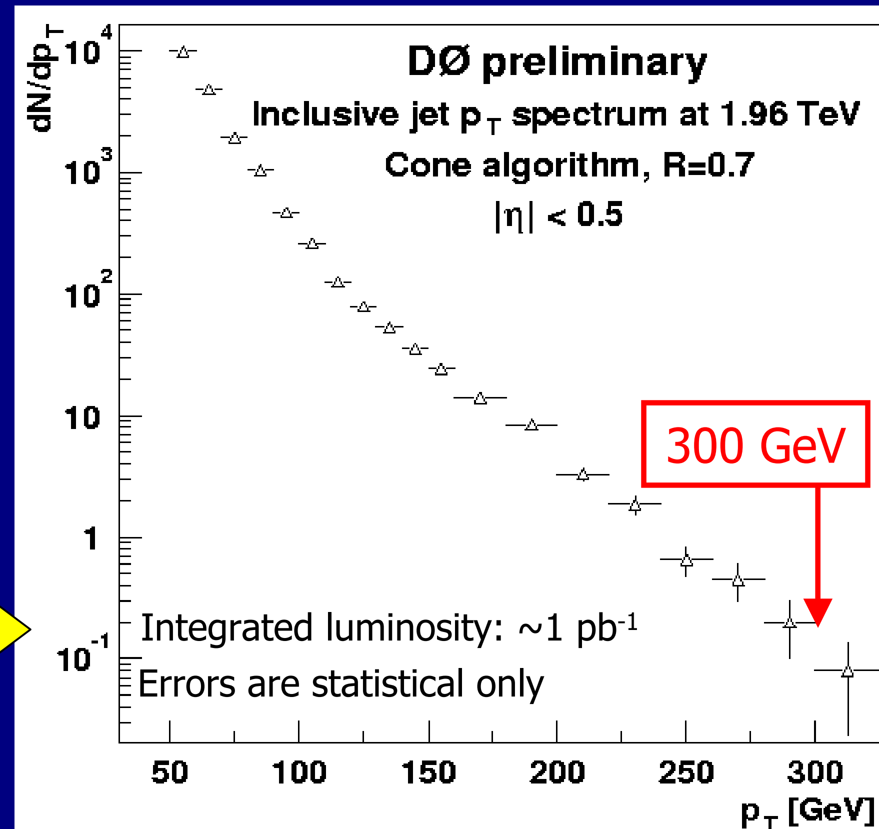


= evidence for b-quark content

On the road to jet cross sections

γ + jet events are used to derive the jet energy scale



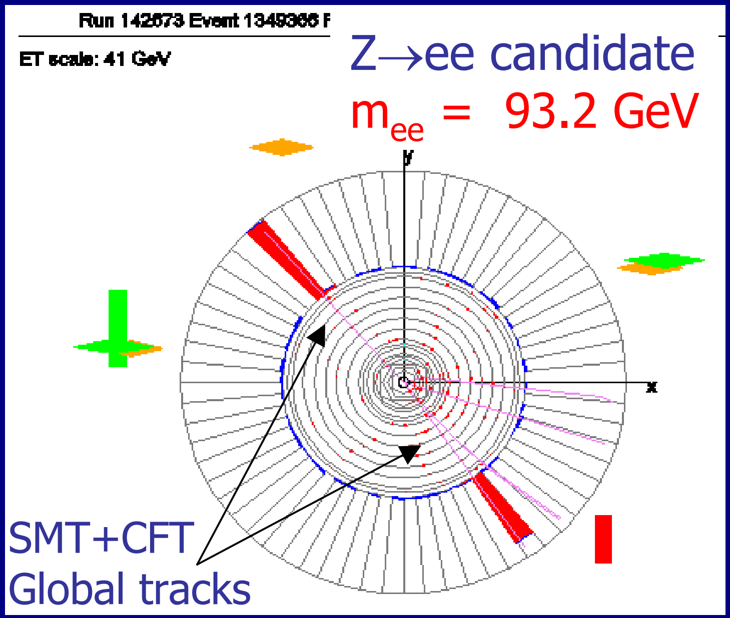


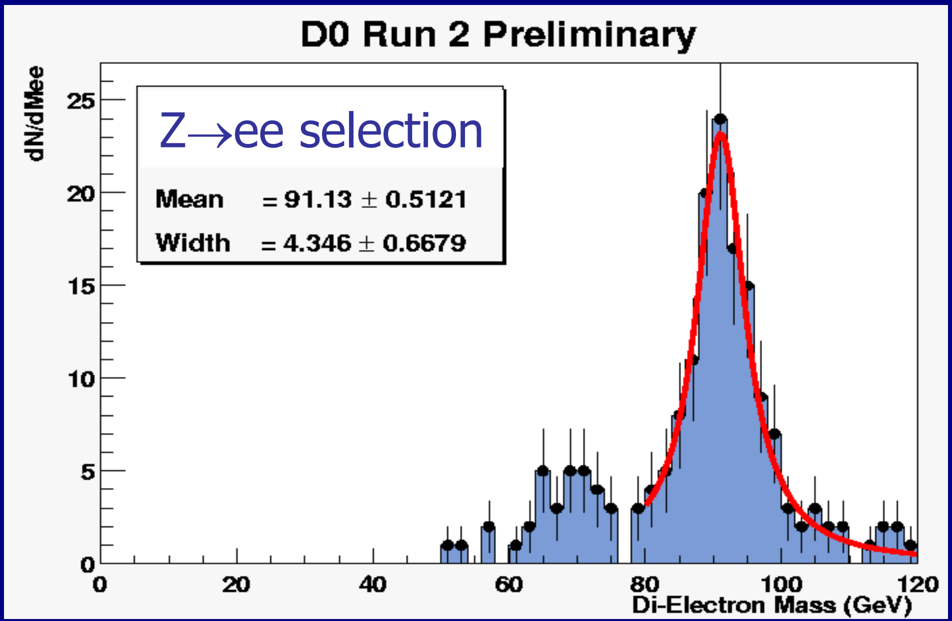
"Run 2 cone" algorithm

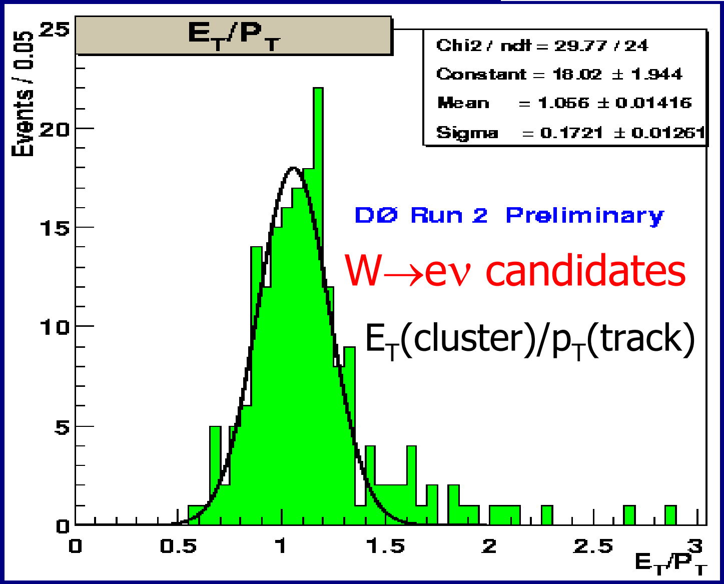
Preliminary correction for jet energy scale, but no unsmearing of resolution effects

Note that the jet cross section for E_T > 400 GeV is ten times larger at 1.96 TeV than at 1.8 TeV

On the road to electroweak physics



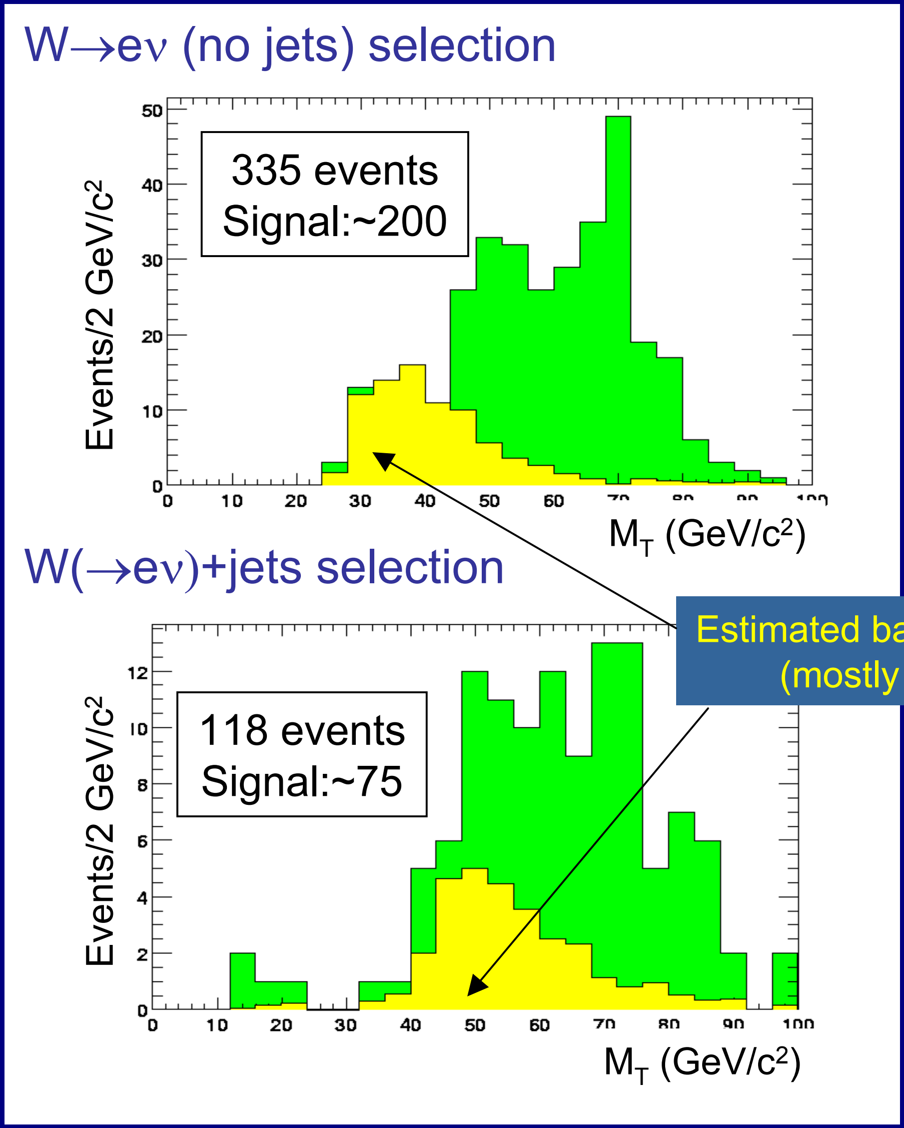




Require ≥1 track-EM cluster match

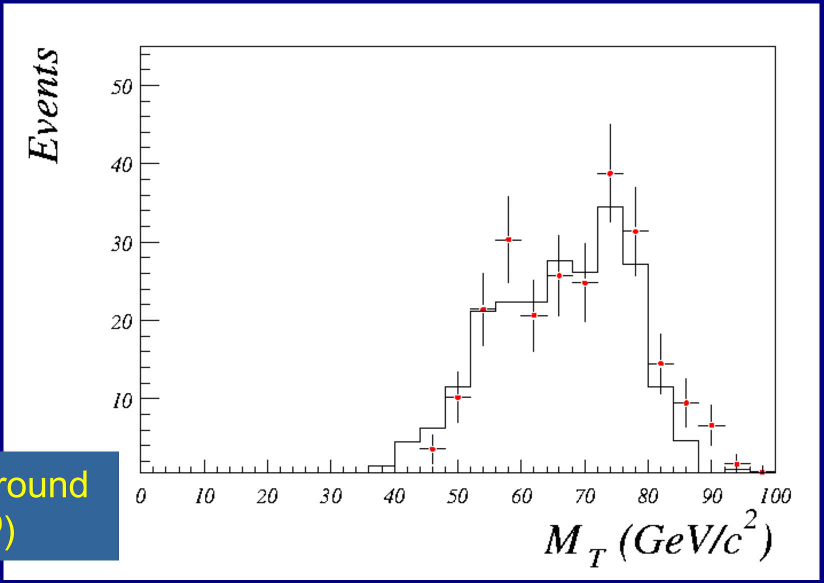
Z cross section extracted
Consistent with expectations

$W \to e\nu$



Estimated background (mostly γ, π^0)

- Background subtracted transverse mass agrees with Monte Carlo:



W cross section extracted Consistent with expectations

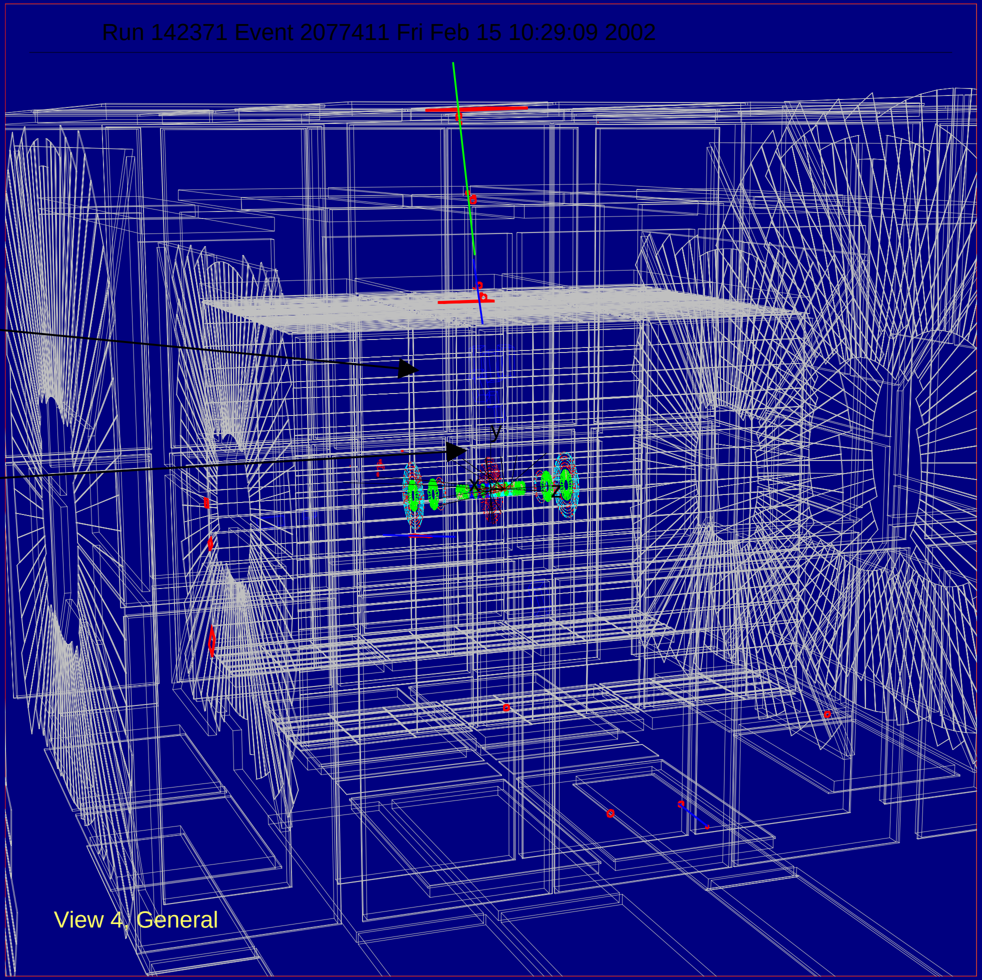
W → μν

Muon p_T = 37 GeV, charge -1

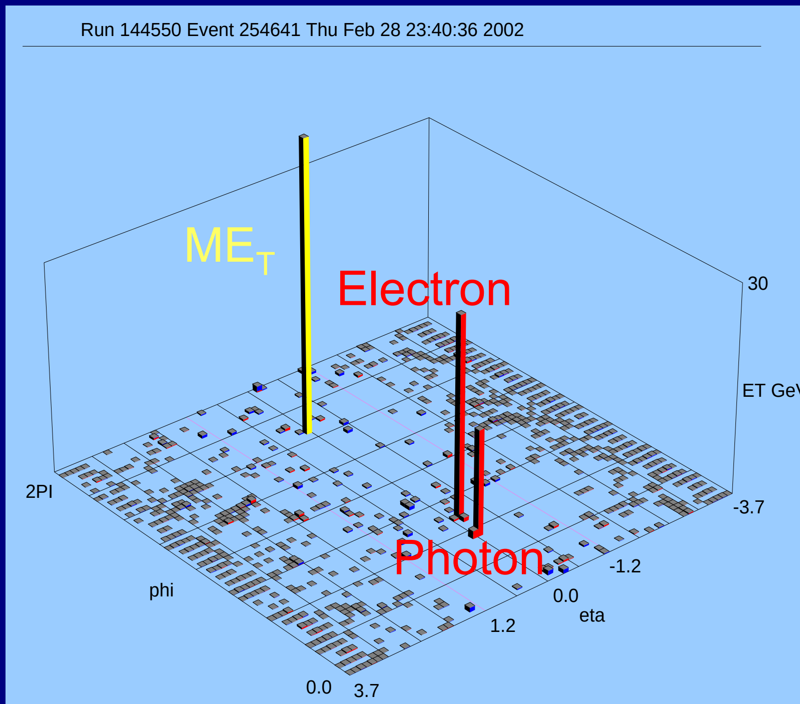
Transverse mass = 78 GeV

2.6 GeV (MIP) in calorimeter

11-hit central track with DCA = 50μm



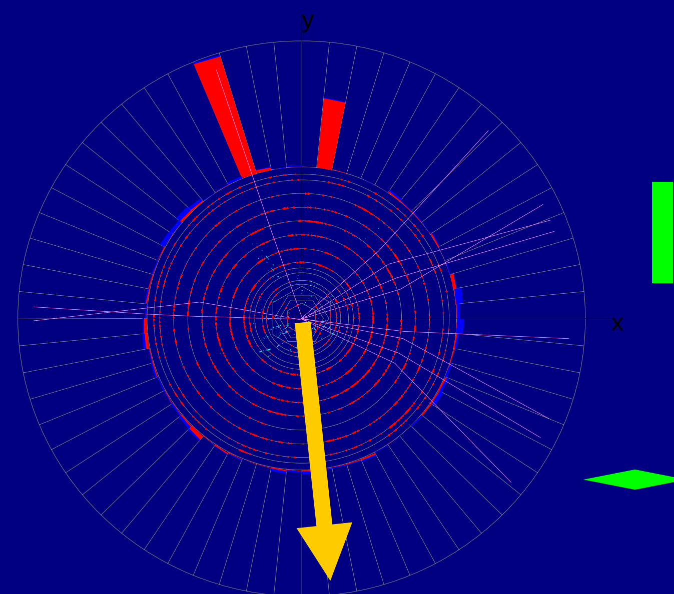
$W\gamma$ Candidate Event



e	γ
E_T = 31.8 GeV	E_T = 17.8 GeV
p_T = 16.4 GeV	η = -0.01
η = -0.13	φ = 1.42
φ = 1.89	No track match
Charge = -1	
ME_T = 45 GeV, $M_T(e+ME_T)$ = 76 GeV $M_T(e\gamma+ME_T)$ = 95 GeV	

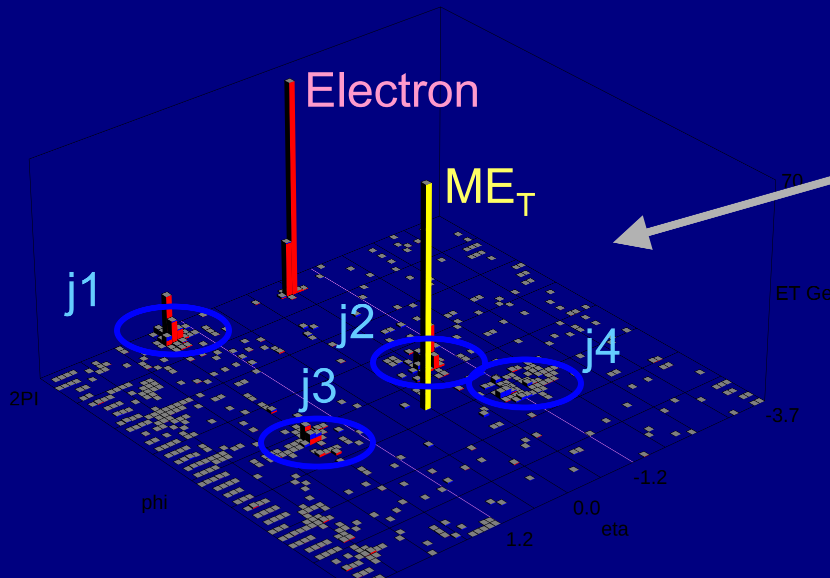
$W\gamma$ events test anomalous VB couplings and other new physics scenarios

$M_T(e+ME_T)$ = 76 GeV
$M_T(e\gamma+ME_T)$ = 95 GeV



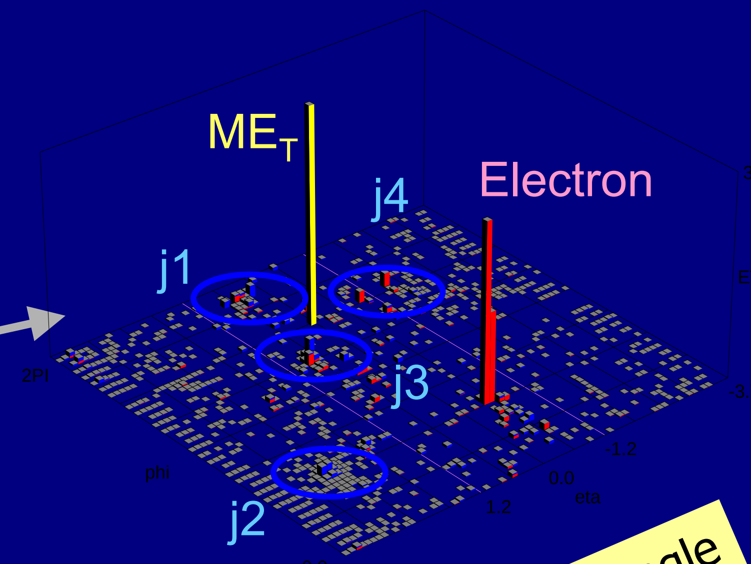
DØ Run 2 Preliminary

On the road to top: W+4 jets candidates



e1	j1	j2	j3	j4
E_T = 99 GeV η = -0.53 φ = 5.94 Low-p_T track match	E_T = 68 GeV η = 1.62 φ = 6.03	E_T = 57 GeV η = 0.69 φ = 3.38	E_T = 35 GeV η = 1.27 φ = 2.29	E_T = 26 GeV η = 1.83 φ = 2.90
ME_T = 62 GeV, $M_T(e1+ME_T)$ = 156 GeV				

e1	j1	j2	j3	j4
E_T = 52 GeV η = -0.51 φ = 1.63 Low-p_T track match	E_T = 28 GeV η = 0.73 φ = 3.82	E_T = 24 GeV η = 2.41 φ = 1.62	E_T = 21 GeV η = 0.52 φ = 5.80	E_T = 20 GeV η = -1.43 φ = 4.60
ME_T = 30 GeV, $M_T(e1+ME_T)$ = 79 GeV				

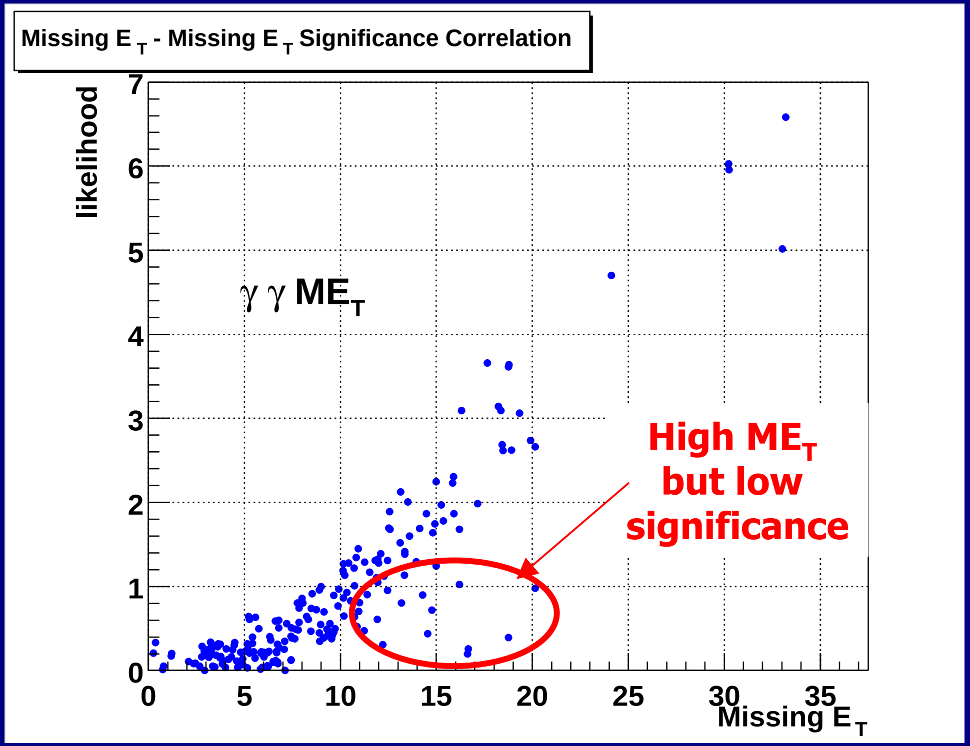


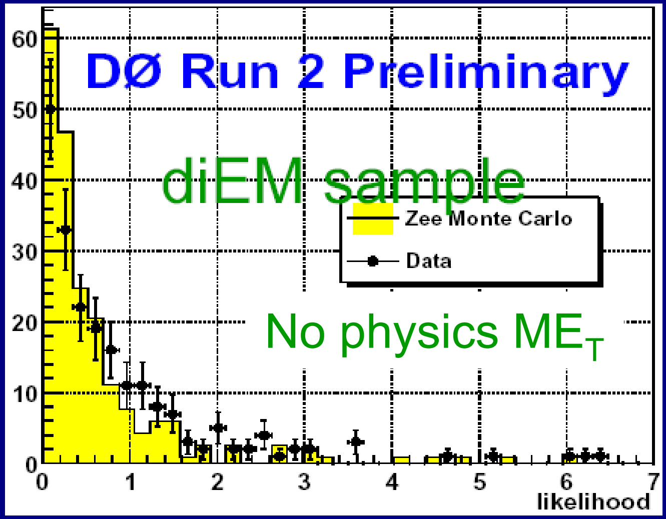
300 pb^{-1} $\rightarrow$ roughly 4 $\times$ our Run 1 top sample
\+ significantly improved S/B from vertex b-tagging
2 fb^{-1}: $\delta m_t \approx$ 2.7 GeV; 15 fb^{-1}: $\delta m_t \approx$ 1.3 GeV (per expt.)

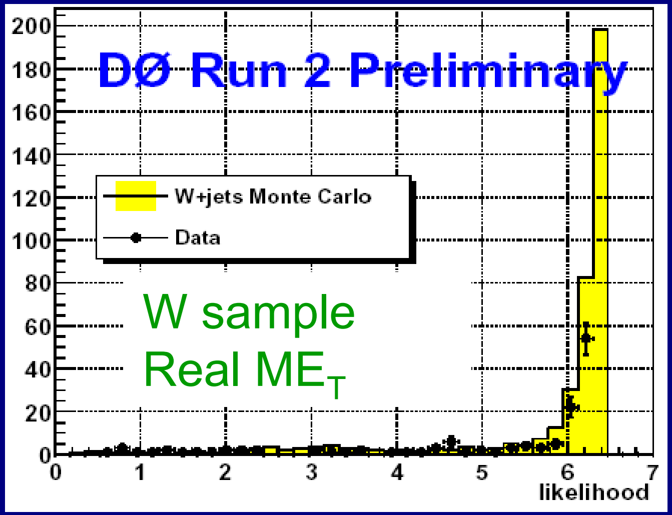
\+ observe single top production

On the road to SUSY: understanding Missing E_T

- Use ME_T significance to take into account event topology, found vertices, and known resolutions
  - Low significance – no physics ME_T
  - high significance - ME_T not likely due to mismeasurement
- Monte Carlo can reproduce distributions:

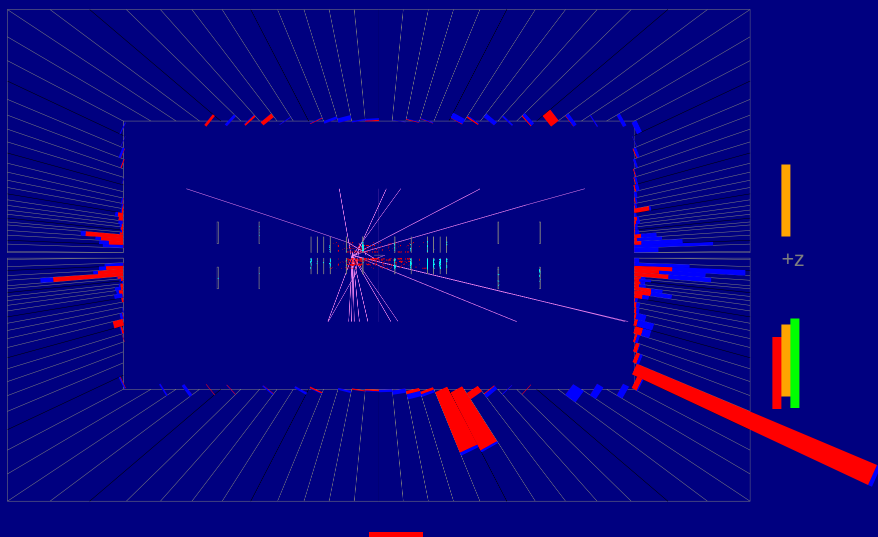


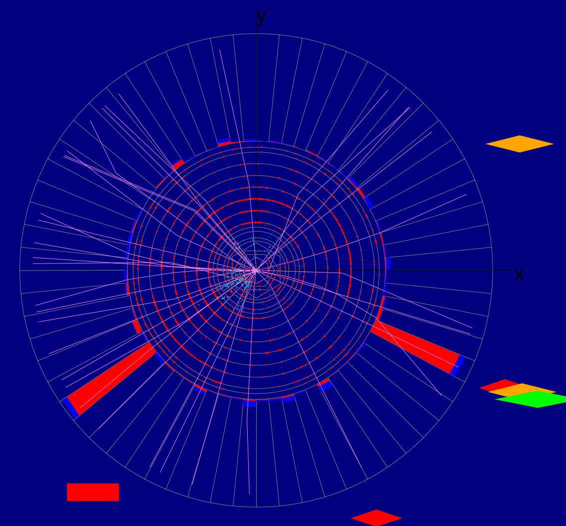


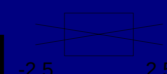


Highest-Missing E_T di-em Candidate

$\gamma\gamma$+ME_T is a signature of gauge-mediated SUSY-breaking



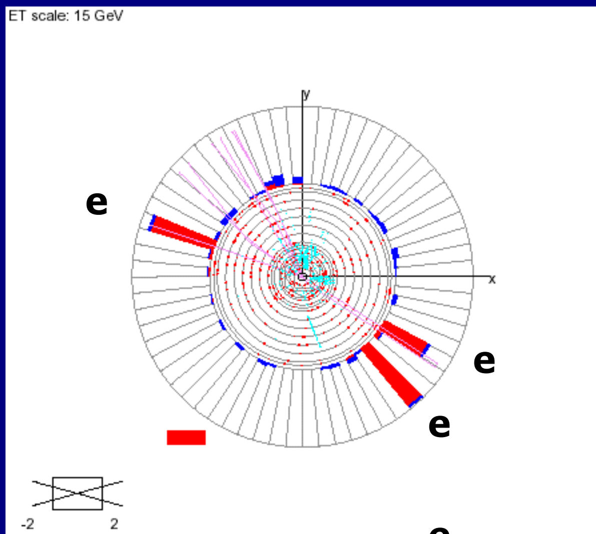


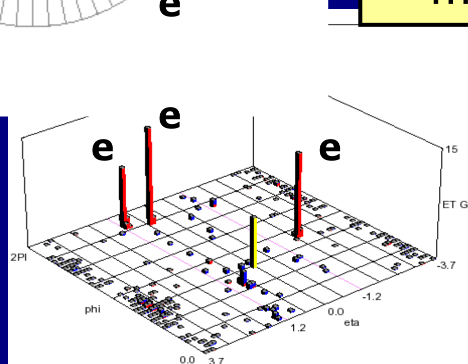


EM1	EM2
E_T = 27.4 GeV η = 0.52 φ = 3.78 Loose match with a low-p_T track	E_T = 26.0 GeV η = 1.54 φ = 5.86 No track match
ME_T = 34.3 GeV; M(diEM) = 53 GeV	

Missing E_T not consistent with a vertex mismeasurement, but can be explained by resolution effects.

Trilepton candidates

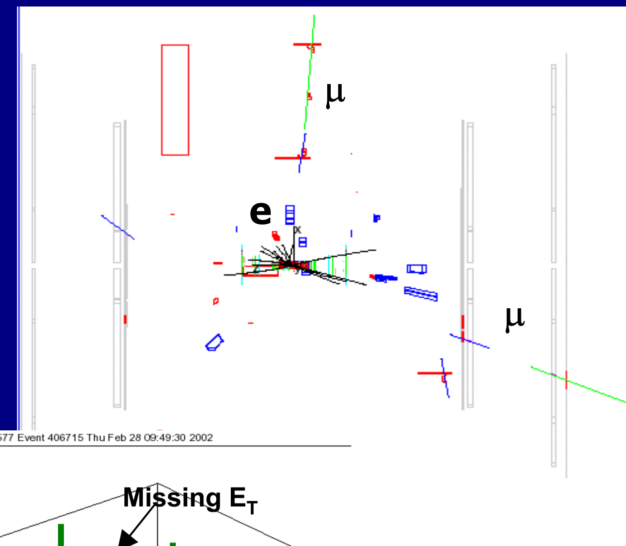


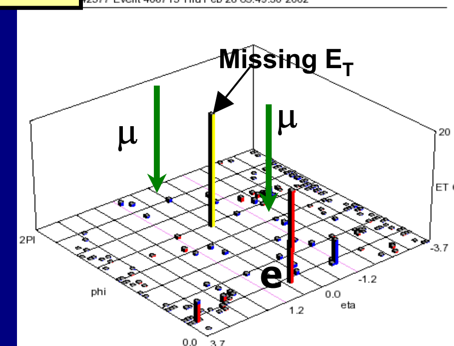


Trilepton events are a Run 2 SUSY discovery channel

$\chi^{\pm}\chi^{0}$ production

With 2fb^{-1}, reach in $m\chi^{\pm}$ is ~ 180 GeV





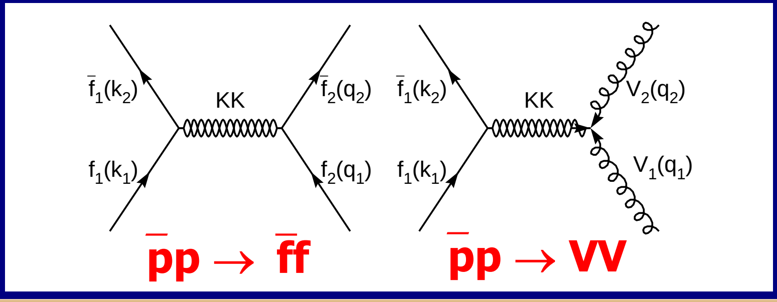
eee

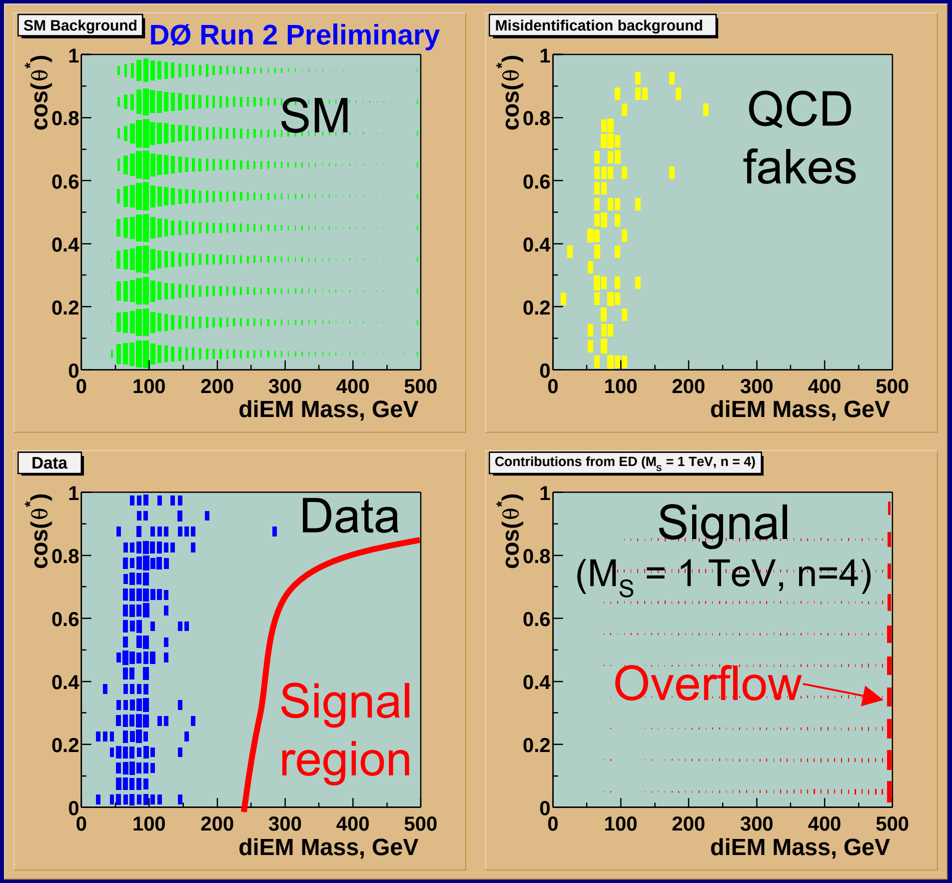
eμμ

e1	e2	e3
E_T = 17.9 GeV p_T = 0.52 GeV η = 0.43 φ = 5.42 Charge = +1	E_T = 13.9 GeV p_T = 10.9 GeV η = -1.94 φ = 2.80 Charge = +1	E_T = 13.2 GeV p_T = 15.1 GeV η = 1.06 φ = 5.72 Charge = -1
m_{e1e2} = 55.7	m_{e1e3} = 10.8	m_{e2e3} = 63.5
m_{e1e2e3} = 85.2 GeV/c^2		ME_T =10.7 GeV

e	μ1	μ2
E_T = 19.2 GeV η = 0.40 φ = 0.63 No track match	p_T = 28.2 GeV η = -0.10 φ = 6.20 Charge = -1	p_T = 9.82 GeV η = -1.48 φ = 2.88 Charge = 1
	$m_{\mu\mu}$ = 41.5 GeV/c^2	
ME_T =31.8 GeV		

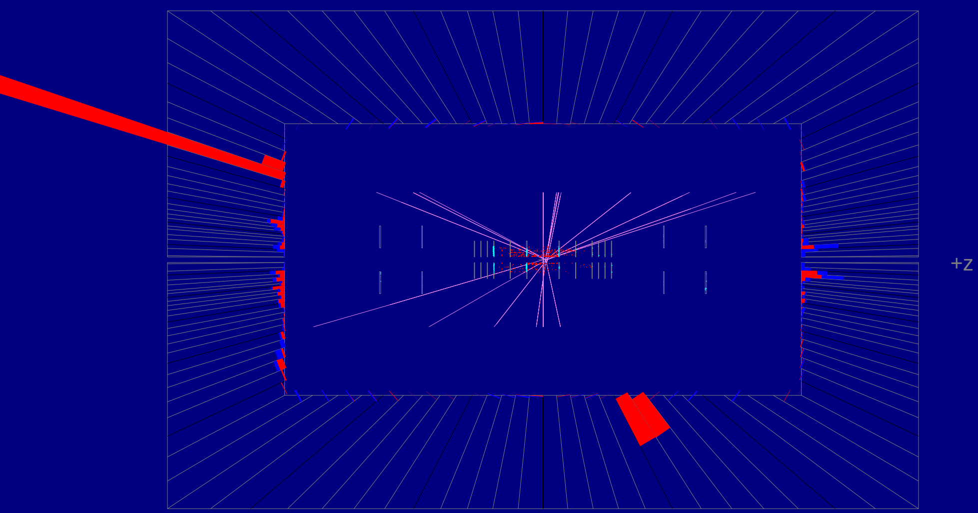
Search for Extra Dimensions

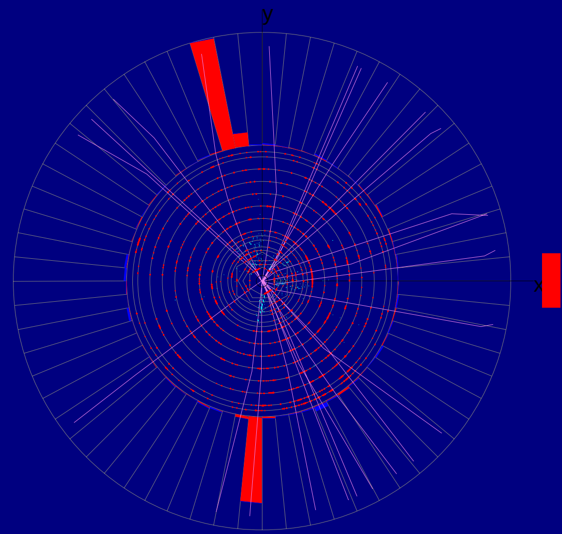




- Search for large extra spatial dimensions through virtual graviton effects
- Follows DØ Run 1 analysis
  - mass and scattering angle maximize sensitivity
- Use both $\gamma\gamma$ and ee events to further increase sensitivity
- Kinematic cuts: $E_t^{e,\gamma} > 25$ GeV, use whole fiducial volume
- Background dominated by Drell-Yan and direct photon production
- Data agree qualitatively with the background predictions

Highest-mass (286 GeV) candidate event: forward topology, typical of background





EM1	EM2
E_T = 91.1 GeV η = -1.83 φ = 1.79 Loose low p_T SMT track match	E_T = 67.1 GeV η = +0.60 φ = 4.65 Loose low p_T CFT track match
M(diEM) = 286 GeV; $\cos\theta^*$ = 0.90; ME_T = 25.9 GeV;	

For n=2 extra dimensions,
DØ Run 1 limit on scale is 1.4 TeV

With 300 pb^{-1}, we probe ~ 1.6 TeV
With 2 fb^{-1}, we probe up to 2 TeV

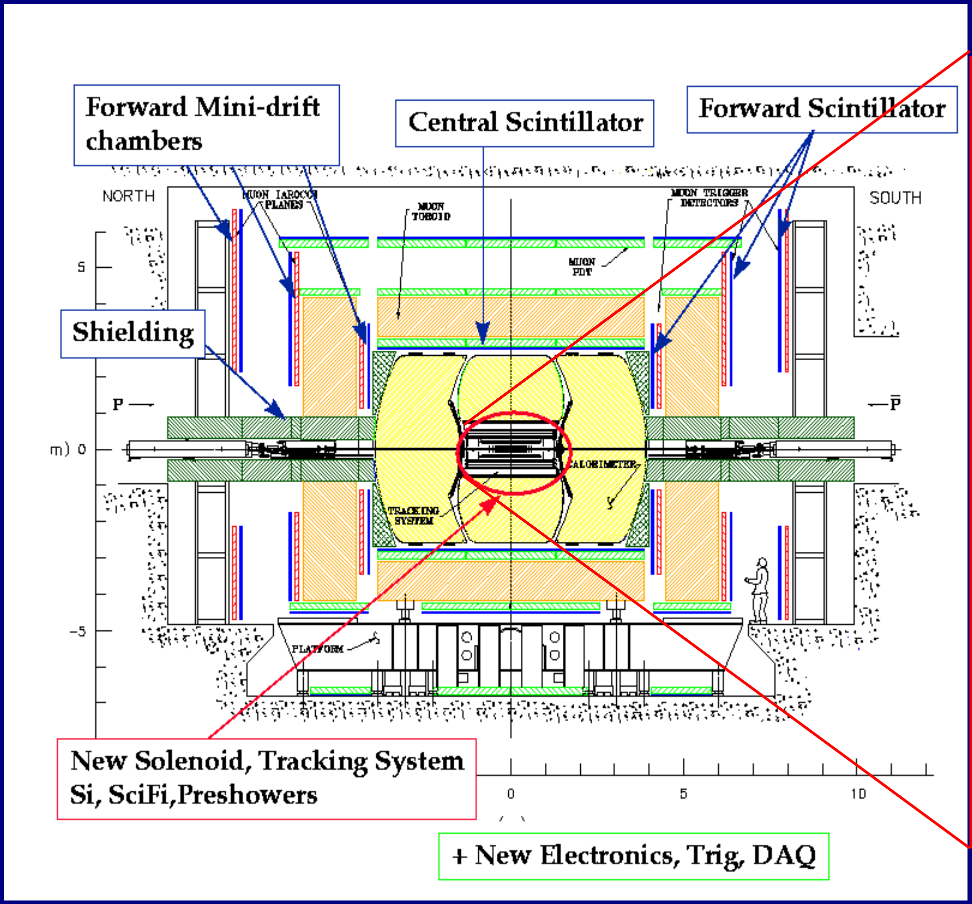
Outlook

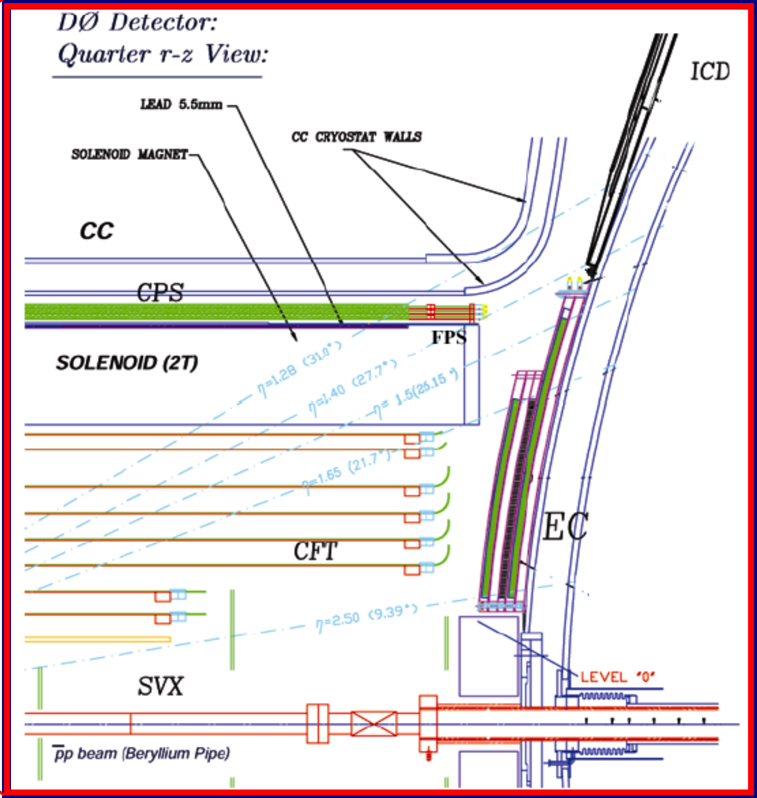
- Enormous progress over the past year in installation, integration, commissioning of the detector and understanding the data
- Preliminary results are very encouraging and indicate that the DØ detector will be able to fully exploit the rich physics opportunities of Run 2
  - We are reconstructing electrons, muons, jets, missing E_T, J/ψ, W's and Z's
  - We know what needs to be done and we are working very hard to
    - commission the remaining detector elements and optimize detector, trigger and DAQ performance
    - understand calibration and alignment
    - improve selection and reconstruction procedures

We are on the way to exciting physics

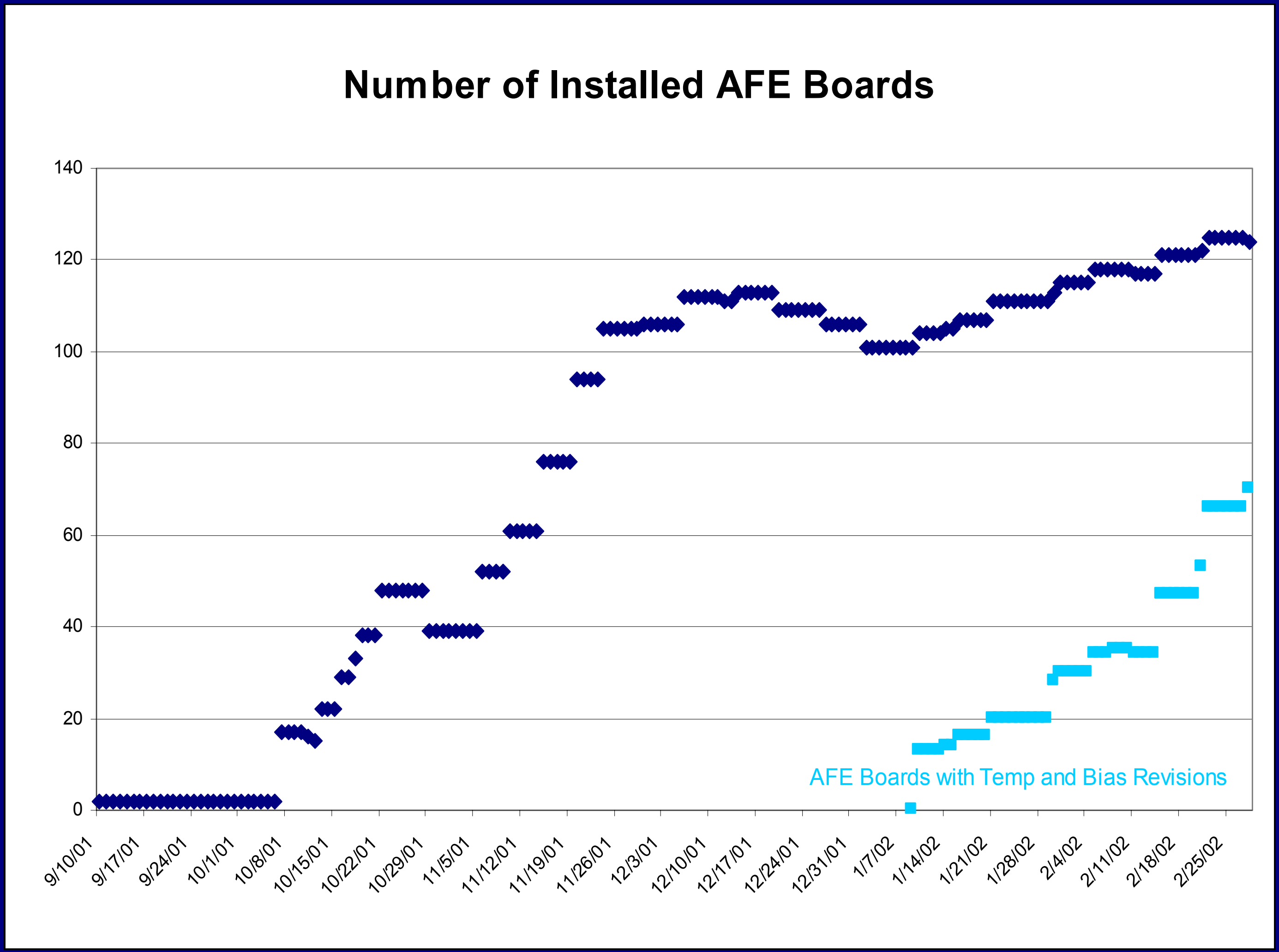
backups

The Run 2 DØ Detector



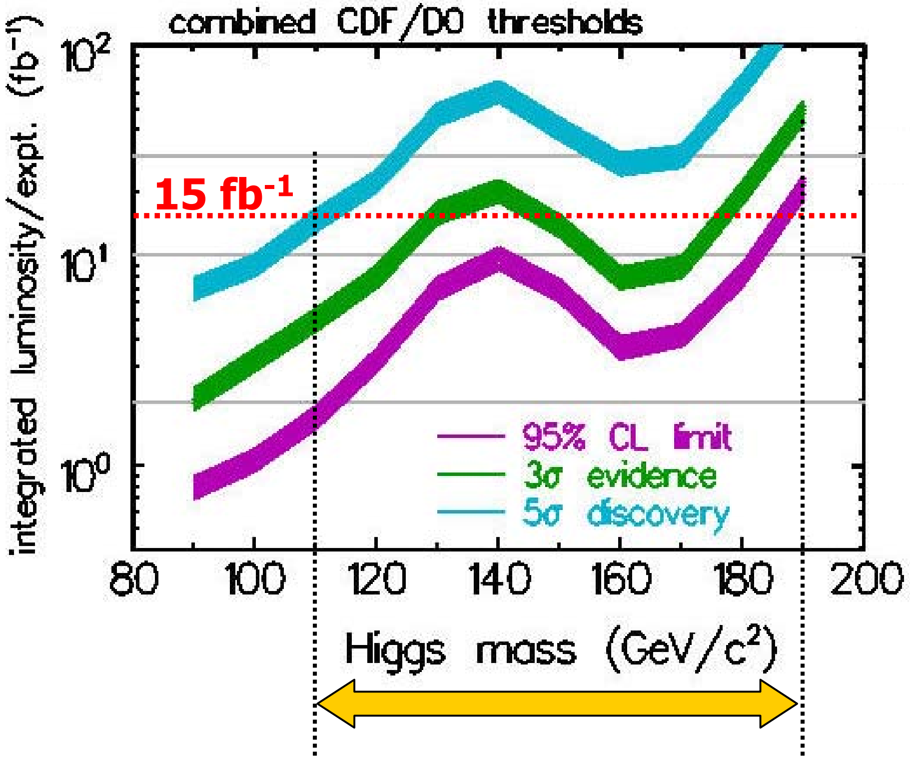


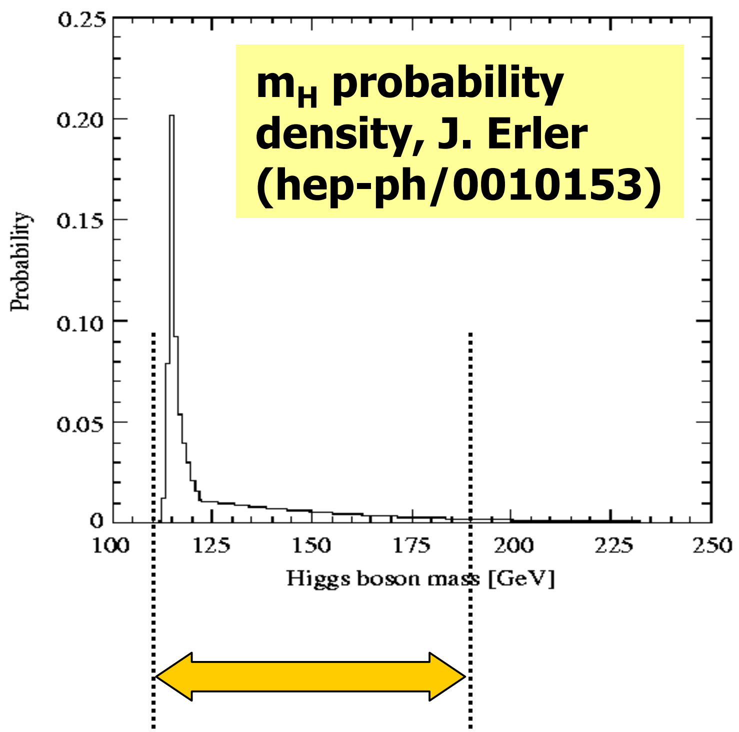
- Builds on the firm foundation of the Run 1 calorimeter and central muon system
- Adds magnetic tracking, silicon, new forward muon system, new electronics and three level trigger



Number of Installed AFE Boards
140
120
100
80
60
40
20
0
9/10/01
9/17/01
9/24/01
10/1/01
10/8/01
10/15/01
10/22/01
10/29/01
11/5/01
11/12/01
11/19/01
11/26/01
12/3/01
12/10/01
12/17/01
12/24/01
12/31/01
1/7/02
1/14/02
1/21/02
1/28/02
2/4/02
2/11/02
2/18/02
2/25/02
AFE Boards with Temp and Bias Revisions

Tevatron Higgs mass reach





110-190 GeV

No guarantee of success, but certainly a most enticing possibility

Indirect Constraints on Higgs Mass

- Future Tevatron W and top mass measurements, per experiment

	Δm_W
2 fb^{-1}	±27 MeV
15 fb^{-1}	±15 MeV

	Δm_t
2 fb^{-1}	±2.7 GeV
15 fb^{-1}	±1.3 MeV

Impact on Higgs mass fit using Δm_W = 20 MeV, Δm_W = 1 GeV, $\Delta\alpha = 10^{-4}$, current central values
M. Grünewald et al., hep-ph/0111217